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THE QUARTERLY REVIEW of BIOLOGY

PROBLEMS IN INVERTEBRATE CHEMORECEPTION

BY EDWARD S. HODGSON

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INTRODUCTION

CHEMORECEPTION in invertebrate animals has attracted several types of interest among biologists. Natural historians have long been impressed with the large number of cases in which responses to chemical stimuli underlie behavioral responses and important ecological relationships among invertebrates. More recently, physiologists have become aware of the invertebrates as experimental animals of choice in the study of many problems concerning the fundamental mechanisms of chemoreception. Farthest removed from direct concern with behavioral and ecological problems are those physiologists who are intrigued by the incredibly small amounts of chemicals which activate the chemoreceptors of invertebrates, and who look upon this area of sensory physiology as a promising approach to increased understanding of specific molecular interactions in living cells.

Despite the breadth of this spectrum of interests, ranging from the behavior of intact organisms in their normal environments to the reactions of a few molecules within a minute part of an organism, the relevant scientific literature consists predominantly of natural history. Formidable technical problems have for a long time prevented work on any other level. Recent technological refinements, however, have made it possible to study the physiology of some primary chemoreceptor cells directly, and a rapidly increasing emphasis upon this level of physiological information can be expected. It is predominantly through accumulation of information about the physiology of the primary chemoreceptors that sound interpretations at the molecular level can ultimately be expected.

Because of the new trends which appear probable in experimental work on chemoreception, this is an especially appropriate time to take stock of the past observations which suggest some of the areas in which future work might be most rewarding. The present review is directed toward two objectives. One is to analyze the bearing which the data on invertebrates have on the development of general concepts in this area of sensory physiology. In so doing, emphasis tends to fall upon similarities in the physiology of chemoreception, not only among invertebrate animals but in comparison to vertebrates as well. However, the differences in the methods by which various animals carry on a function usually are important for understanding the ways of life peculiar to the animals themselves. Since differences in the chemical senses influence host-parasite and other relationships of theoretical or economic interest, the dissimilarities as well as the similarities in chemoreception raise questions of more than anecdotal significance. The analysis of such differences and their significance is the second objective of this review. It is hoped that this type of treatment will help to retain and strengthen the connecting ideas between strictly physiological studies and the central concepts of

biology concerning the evolutionary significance of physiological adaptations and the behavior of animals.

References to many studies on chemoreception in vertebrates, especially in mammals, have been considered essential for comparative purposes, but problems arising primarily from investigations of human physiology have been avoided here. Important reviews on chemoreception, written primarily with the physiology of human olfaction and gustation in view, have included those by Moncrieff (1946), Beidler (1952), Gerebetzoff (1953), Le Magnen (1953), and Wenzel (1954). The general review of Jahn and Wulff (1950) also covers information not touched upon in the present paper.

ECOLOGICAL PROBLEMS IN CHEMORECEPTION

Historically, awareness of chemoreception as an important sensory mechanism stemmed from observations on the behavior of intact organisms, and the problems raised by this type of study will be discussed first. Because of their greater numbers, variety, and remarkable development of the chemical senses, invertebrate animals have been common objects of such studies. The aquatic environment in which most invertebrates evolved probably has strongly influenced the degree to which they depend upon the chemical senses. Turbidity and dim illumination in aquatic habitats impose severe limitations on vision, and would be expected to confer considerable selective advantage upon the development of sensitivities to chemicals in the surroundings. This is illustrated in greatly exaggerated form by the hyper-development of the chemical senses existing (though without critical physiological study) among cave-dwelling invertebrates (Nicholas, 1955). The early phylogenetic appearance of the chemical senses suggests also that the specializations in cell function necessary for operation of a chemoreceptive function may be less severe than the modifications involved in differentiation of other types of sensory receptors. At any rate, sensitivities to chemical stimuli reached unparalleled development in the evolution of invertebrates and continue to serve a variety of basic functions for these organisms. Sensitivity and reaction to particular kinds of chemicals in the environment may determine the exact locality, host, or food plant sought by an animal. Chemicals emitted by members of a species may be important in the reproductive behavior of the species or may isolate the interbreeding population from closely related animals.

It is interesting to compare this situation with that prevailing among the vertebrates. The aquatic vertebrates which arose relatively early in the evolution of their subphylum retained much of the dependence upon chemical senses. This might be illustrated by the fact that minnows can detect chemicals from a water rinse of an aquatic plant after the rinse has been diluted more than ten thousand times, or can respond to chemicals introduced into water from brief contact of the water with glassware (Walker and Hasler, 1949). While the higher vertebrates can sometimes detect certain chemicals at great dilutions, and the trailing abilities of some carnivores are well known, there can be little doubt that much of the sensitivity to chemical stimulation has been lost in higher vertebrates. In the case of the primates, at least, the diminished importance of chemoreception can be attributed to the arboreal environment from which the group radiated (Young, 1950). Such an environment would confer a higher selective advantage upon optic and auditory senses than upon the chemical senses.

As a consequence of the disproportionate development of the chemical senses among invertebrates, the literature concerning these animals includes most of the information about the ecological significance of chemoreception. The enormous volume of the literature necessitates a selective coverage. However, the general problems which emerge from an evaluation of these observations would probably be much the same even if more, or if different, examples were chosen as illustrations.

1. *Chemotaxis and habitat selection*

Under this heading can be placed an extensive series of observations on invertebrates from many phyla. The first reported observations on chemotaxis were made by Pfeffer in 1884. He demonstrated chemotaxis in *Bacterium termo* and in the spermatozoa of ferns. Engelman (1894) later demonstrated that *B. termo* and *Spirillum* move into different, presumably optimal, oxygen concentrations in the surrounding medium. This reaction was shown to be so delicately controlled that an individual bacterium might react to the oxygen produced by a single specimen of another bacterium (about one hundred-billionth of a milligram of oxygen). Buller (1900) found that the

sperm of ferns and clubmosses reacted positively to malate and citrate anions, which played an important part in fertilization. Methods similar to those used by Pfeffer and his associates were also employed by Leber, who first reported chemotaxis in leucocytes (consult the review of McCutcheon, 1946). More recently, Bonner (1947) has demonstrated by a different technique that the aggregation of myxamoebae of the slime mold *Dictyostelium* into a single unified organism occurs through chemotaxis. Although many descriptions of chemotaxis of adaptive significance in unicellular (or acellular) animals have been made, there has hardly been a start at a satisfactory physiological analysis of the mechanisms through which it occurs.

The selective advantage of many of these cases in assuring the continued food supply and life of the species is obvious. Problems remain, however, concerning other instances in which the full significance of the chemically mediated responses is not known. For example, Edmondson (1944), during very extensive studies on the ecology of sessile rotifers, noted that *Collotheca gracilipes* is capable of attaching itself to several genera of plants and to glass surfaces. But in the vast majority of cases in natural habitats and under experimental conditions this rotifer selects *Utricularia vulgaris* as a substrate, even when other plants or artificial substrates are more abundant. Furthermore, *Collotheca* is usually found on fresh green leaves near the growing tip of the plant. Reasoning from these observations, Edmondson devised experiments which showed that the older leaves emit a substance repelling the rotifer larvae. This substance is soluble in weak ammonium oxalate solution and is thought to be a pecten. Among the selective factors ultimately responsible for these chemically mediated substrate preferences, one might suspect changes in the longevity or reproductive capacity correlated with population density, as already known in another species of rotifer (Edmondson, 1945). Similar problems are raised by many other studies in the literature.

2. *Chemoreception in mating behavior and sexual isolation.*

Numerous investigations have shown relationships between mating behavior and the chemical senses. The classic instances among insects are so well known that they need not be discussed again here (consult Jahn and Wulff, 1950). Fewer studies have experimentally analyzed the precise manner in which chemical stimuli participate in the reproductive behavior of a species. In the simplest cases, the responses to chemical stimulation may have a quite indirect effect upon mating. Food preferences of the fly *Sarcophaga*, while apparently playing no part in the actual selection of individuals of the opposite sex, are important in bringing the sexes together in the vicinity of food (Thomas, 1950). A more specific type of chemical stimulus causing aggregations of the housefly *Musca* has been demonstrated by Barnhart and Chadwick (1953). Houseflies visiting a bait contribute to it some substance ("fly-factor") which enhances the attractiveness of the bait to other flies. The substance has not yet been chemically characterized, nor has the species specificity been tested. However, such a phenomenon must have a considerable influence in bringing together the individuals which constitute an interbreeding population. The most precise analysis of the role of chemoreception in reproductive behavior has been made with *Drosophila*. Mayr (1950) found that sexual isolation between *D. pseudoobscura* and *persimilis* almost completely disappears under optimal experimental conditions if the antennae of the females are removed. Olfactory stimuli from males of the same species apparently act by raising the general level of excitability or receptivity of the female until a threshold of readiness for mating is reached. The data also suggest that partial sexual isolation between some different strains of the same species are due to differences in odors of the strains. While most of the chemoreceptors involved can be localized on the antennae, the antennaeless females of *D. melanogaster* are still capable of a fair degree of discrimination through use of still unidentified receptors. Spieth (1952) has concluded that psychological isolation of this type characteristically precedes any morphological differences in the evolution of species.

3. *Host-parasite and host-commensal specificities mediated by chemoreception*

When the habitat of an animal happens to be a tissue of another animal or of a plant, the reaction to a chemical stimulus from the host is often the key to the host-parasite specificity. Since at each stage of a parasite's life cycle it is generally in a different environment and has a distinctive pattern of behavior, each stage in the life cycle presents special problems. As one example, the re-

action of a freely moving miracidium of a digenetic trematode might be considered. The miracidium larva of *Opisthorchis flineus* will attach itself to the prosobranch snail *Bithynia leachi*, but not to *B. tentaculata*, which is usually more abundant in the same environment. This reaction is apparently mediated by chemical stimuli from the host (Baer, 1951), but the effective chemicals have not been identified, nor has their precise origin within the host been determined. It seems probable that chemoreception also mediates behavior in a number of similar instances, such as that described for *Schistosoma*, one species of which penetrates only oncomelonid snails while another species is restricted to planorbid snails (Baer, 1951). The fact that these studies on host-parasite specificity can often be carried out under experimental conditions in the laboratory, as well as in the field, justifies some optimism regarding further experimental analysis of these types of ecological observations.

As has already been noted for the role of chemoreception in reproductive behavior, the actual mechanisms involved in responses of parasites to chemical stimuli from their hosts may be more complex than is evident from a purely descriptive report alone. This is the case with the freshwater mite *Unionicola*, which lives as a parasite between the gills of the mussel *Anodonta* (Welsh, 1931). A negative response to light is necessary if the parasite is to remain within the host. However, mites experimentally removed from their hosts and host materials move toward light. When a small amount of water from the mantle cavity or an extract of the host is added to the water containing the isolated mites, they immediately reverse to a light-negative state. The chemical stimulus from the host is quite species-specific, for stimulation with fluids or extracts from seven other species of mussels produced no reversal in the light response of *Unionicola* taken from *Anodonta*. The mites are also specific in their capacity to react, for studies on three other species demonstrated that they reacted only to chemical stimuli from their particular hosts in each case.

In view of the abundance of host-parasite and host-commensal associations found among marine invertebrates, it is surprising that before 1950 there were no extensive efforts to analyze the behavior through which these associations are formed. The polychaete *Arctonoë*, which is usually a commensal with the starfish *Evesterias*, was the first example of a marine commensal to be experimentally studied from this viewpoint (Davenport, 1950). In order to determine how the two species formed their association, the behavior of the polychaete was studied in an apparatus similar to a Y-tube olfactometer. This apparatus was so arranged that a worm placed in it would eventually have to orient itself toward a flow of sea water coming from an aquarium containing *Evesterias*, or else would orient toward water which had not been in contact with the starfish. Davenport was able to obtain clear statistical evidence that the echinoderms produce substances which act as powerful attractants for their polychaete commensals. The reaction is species-specific. The attractants are not stable for 24 hours in sea water, and do not readily diffuse through dialyzing membranes (Davenport and Hickok, 1951). One of the most remarkable features of this relationship is that if a starfish is injured, the chemicals which diffuse from it actually repel the commensal worms. A selective advantage in assuring the worm of a living starfish is indicated. The repellent effect of the injured hosts prevents the investigator from locating the attractant portion of the host by testing extracts of pieces of the echinoderm. The repellent effect appears to be analogous to the emission from the injured skin of fish of a chemical olfactory stimulus ("Schreckstoff") which brings about rapid dispersal of the school of fish (von Frisch, 1941).

Bullock (1953) has recently described an instance in which the specific chemical sensitivity of certain gastropods has a selective advantage different from those types thus far discussed. Species of limpets living in regions invaded by predatory starfish (*Pisaster*) exhibit a characteristic escape reaction when approached by the starfish, even before there is any contact between the animals. Starfish extracts also evoke the reaction. However, high-tide species of limpets, living where the starfish are not found, do not show this reaction, and the behavioral difference can be used to distinguish between the high-tide and low-tide species of limpets where their ranges overlap.

The most extensive observations on the specificity of chemoreception-mediated reactions have been made upon the phytophagous insects and their host plants. These have been recently reviewed by Dethier (1954), and the material will not be duplicated here. One important fact that emerges from the entomological literature is that single chemical compounds often act as "token stimuli" by means of which an insect recognizes

the stimulus source. In the case of plants, chemical analysis of the stimulatory products usually finds them to be alkaloids or essential oils (Dethier, 1954). No chemical studies of a comparable degree of refinement exist for other classes of invertebrates and are much to be desired as a basis for understanding the evolution of those ecological relationships that depend upon chemoreception.

The identification of most stimulants is rendered difficult by the small amounts of the substances which are usually available. The quantities are generally inadequate for the usual methods of chemical analysis. Wharton, Miller, and Wharton (1954) have recently described a bioassay used as an adjunct to the chemical analysis of an odorous substance found on female roaches. The scent of virgin female roaches produces a characteristic and easily recognized behavior in male roaches, and the behavior of the males may be used as a delicate, even partially quantitative, test for the presence of the attractant in extracts of the substance from the females.

4. *The basis for selectivity of responses to chemical stimuli*

A challenging problem of general significance arises from attempts to account for the selectivity which characterizes most ecologically important behavioral patterns mediated by the chemical senses. Granting the adaptive significance of the arrangement by which animals may react to chemicals originating in the opposite sex of their own species and not in any other species, or to chemicals in their particular food and not in any other, what mechanisms operate within the animals to make this selectivity possible? And how are these mechanisms changed in the evolution of new races and species with different behavioral patterns? Both genetic and non-genetic mechanisms seem to be involved in what is known of the answers to these questions.

Most of the fragmentary evidence about the genetic factors concerned has been derived from studies on food preferences of phytophagous insects, and has been discussed in detail by Dethier (1954). However, a few of the conclusions should be noted here. At least one instance is known of a radical change which occurred in the feeding habits of a monophagous species within historic time. It seems most reasonably explained as the result of mutation (Woods, 1915, as cited by Dethier, 1954). The many cases of monophagous forms splitting off from originally polyphagous populations are best explained as selection of different genetic strains already present in the polyphagous population. The numbers of genes which may control feeding preferences are unknown. Hovanitz (1944) has shown that the dietary requirements of two races of *Colias* butterflies have a multifactorial genetic basis. However, neither oviposition nor larval feeding preferences occur in these two races, and in any case it is unlikely that identical genes control the physiology of chemosensory mechanisms and dietary requirements. Genetic studies are chiefly handicapped by the difficulties of measuring behavioral patterns as phenotypic characters. It is at least conceivable that changes in the functioning of chemoreceptor cells, as studied by modern physiological methods, might provide more suitable characters for genetic analysis.

There is still less evidence which would indicate what the actual physiological differences might be between animals responding differently to the same chemical stimuli. Are they differences limited to the chemoreceptors themselves? Do the chemoreceptors act as highly selective filters, activated only by one or a few chemicals? Are there central nervous mechanisms which differentiate a variety of signals coming from a single chemoreceptor cell responding to a variety of chemicals? The answers to these questions will depend upon carefully combined physiological and behavioral studies, and reference to some of them will be made again later in the discussion. For the moment, the behavioral studies will be considered alone.

General differences in the sensitivities of animals to chemical stimuli can sometimes be correlated with differences in the numbers or distribution of chemoreceptors. Liebermann (1926), in a comparative study of the sensory structures of flies, found significant differences in the numbers of chemoreceptors in many different species. Those species feeding on flowers were found to have fewer olfactory receptors than the species feeding on carrion. Within a single species of a social insect, differences in the numbers of antennal chemoreceptors have been noted in various castes (Hodgson, 1954). In this instance, allometric growth during development appears to underlie the differences in sensory equipment, and thereby to provide a partial explanation for caste differences in general reactivity to chemical stimulation, important in the division of labor within the colony. Since the castes of ants studied have the same

genotype, and the degree of allometry is probably determined only by feeding differences (Wilson, 1953), it would be a mistake to think of non-genetic influences on the chemical senses as necessarily slight or easily changed.

The pioneer work on non-genetic changes underlying behavioral reactions to chemical stimuli was performed on insects (Walsh, 1864). The conclusions reached at that time were formulated in the light of Darwin's then recently published *Origin of Species*, and show that Walsh exercised a far-reaching insight into the implications of his own observations. Essentially, he noted that a species of insect which can feed on many kinds of plants will, if reared for many generations on only one of its potential food plants, eventually tend to select that one particular food plant upon which to deposit its eggs. The population with the specialized host plant was designated as a "phytophagic variety." Walsh postulated that the "variety" might remain a race, interbreeding with other members of the original population, or it might eventually cease to interbreed with the polyphagic stock. In the latter case, the "variety" would have become a true species. He concluded that speciation of this sort could occur only in very rare cases because the race would have to be isolated by a geographic or some other type of barrier which would prevent interbreeding with other races of the same species. The latter point is especially noteworthy because some more recent workers have been less careful in discussing the evolutionary importance of the phenomenon, and lengthy arguments have been needlessly precipitated. The real significance of the process appears to be in assisting the invasion of new habitats by conspecific populations (Mayr, 1947), and there still have been no critical field studies showing to what exact degree the monophagous races are isolated from parent populations and contribute to the evolution of new species (Andrewartha and Birch, 1954; Dethier, 1954).

An important advance in understanding the mechanisms which bring about this phenomenon was made by Thorpe and Jones (1937). They noted that *Nemeritis*, a hymenopteran endoparasite of larvae of the meal-moth *Ephestia*, found its host entirely by means of chemical stimuli detected by receptors on the antennae. If larvae of the moth *Meliphora* are contaminated with the smell of *Ephestia*, the adult *Nemeritis* will oviposit on *Meliphora*. *Nemeritis* which are reared on *Ephestia* later show no reaction whatever to *Meliphora*, but those reared on *Meliphora*, while still preferring *Ephestia*, are attracted to *Meliphora* in statistically significant numbers when offered a choice of the two host odors. Thus the essential sensory cues mediating the behavior were shown to be chemical, and the phenomenon was then designated "olfactory conditioning." Enough similar data have been accumulated from other studies of insects, and also of nematodes (Steiner, 1925), to prove that the process is of widespread importance (Dethier, 1954).

Though the existing data on olfactory conditioning are extremely interesting, they leave untouched a physiological problem of considerable importance. Is the "conditioning" really a change in some central nervous integration mechanisms, as the name might suggest, or are there other physiological alterations of the animals so affected? One suggestion that might cast some light on the process has come in a brief report by Le Magnen (1949). Following up clinical observations on hormonal changes underlying fluctuations in the olfactory sensitivity of human beings, it was found that the thresholds to certain substances were lowered by injection of the chemical into the patient. The effect lasted as long as thirty days and resembled a process of immunologic sensitization. Le Magnen postulates that a similar process may underlie the species specificity of olfactory responses and the discrimination of a particular host by a parasite. The possibility of a parallel between the action of ingested materials causing olfactory conditioning and of injected materials causing an immunologic reaction has not been explored.

PHYSIOLOGICAL PROBLEMS IN CHEMORECEPTION

It must be conceded that the division of information into "ecological" and "physiological" categories is a distortion based more upon the occupational preferences of biologists than upon any real boundary between the phenomena being considered, and therefore the distinction should not be taken too seriously. The aspect of chemoreception which has excited most interest among physiologists is the problem of understanding exactly how exposure to a stimulating chemical changes the metabolism of a chemoreceptor cell, causing it to initiate some sort of signal which is passed on to another part of the nervous system. There is so little information concerning this problem that data pertaining to the metabolism of

chemoreceptor cells in any organism constitute welcome additions to general thinking on the subject, regardless of whether the fundamental mechanisms of chemoreception are eventually shown to be similar or diverse throughout the animal kingdom.

Experimental approaches to the basic mechanisms of chemoreception have been directed along three lines, all still best expressed as questions. What are the essential specializations of chemoreceptor cells? What are the essential properties of stimuli? What are the reactions between the stimulus and the receptor mechanism which result in excitation of the chemoreceptor cell? These problems will be discussed separately.

The chemoreceptor cell

Morphology and location

The morphology and locations of chemoreceptors are of interest to physiologists chiefly as background information. However, since the success of a physiological study often depends upon the choice of the experimental animal, it seems appropriate to survey briefly the chemoreceptors of invertebrates in order to note a few of the unexploited advantages of various invertebrates for experimental work.

Some chemoreceptors appear to be among the simplest sense organs known. The morphology of the actual receptor cells, apart from supporting tissues, is remarkably similar in many animal groups. The protozoa and sponges may be excluded from consideration in this connection. The difficulties of combined behavioral and histological studies are responsible for the fact that the existence and location of specialized chemosensory areas in members of those phyla are debatable.

Although definite experimental verification of the presumed functions of sense cells of coelenterates is still lacking, these cells are of particular interest from a phyletic standpoint as the earliest examples of specialized sense cells. Elongated cells bearing attenuated distal processes resembling flagella are present in both the epidermis and entoderm (gastroderm) of *Hydra* (Hadzi, 1909; Burch, 1928), while among the scyphozoa the sensory cells may be especially concentrated in pits on the rhopalia. There is an interesting resemblance between the sense cells seen in sections through the sensory pits of the medusa and those in sections through mammalian olfactory epithelium. The proximal extensions of the presumed sense cells of coelenterates are associated with contractile cells or extensions of neurons in the nerve-net (Parker, 1919). Hyman (1940) summarizes the present state of knowledge regarding the function of the sense cells as follows: "These sensory nerve cells, sometimes called *palpocils*, presumably serve as general receptors for touch, temperature, chemical qualities, etc., and do not seem to be morphologically differentiated among themselves for these various functions, although in some coelenterates the sense cells of different parts differ considerably."

The platyhelminths are the simplest animals for which existing data provide an adequate basis for carrying studies on chemoreception beyond elementary anatomical and behavioral observations. A detailed histological study of a turbellarian flatworm by Kepner and Cash (1915) disclosed what appeared to be sensory cells in pits or grooves on the side of the head. Stiff cilia, probably extensions of the sensory cells, line the bottom of the sensory pits. Koehler (1932) later found by ablation experiments that these structures enabled the flatworm to react to chemical stimuli from food. Unfortunately, the bristle-like extensions of the receptor cells are covered with a layer of secretions. It follows from the logical assumption that chemical stimuli go into solution in this mucous layer that a rigidly quantitative control of chemical stimuli reaching the receptors would be extremely difficult. An analogous situation is responsible for one of the main difficulties in experiments on the chemoreceptors of vertebrates. For example, Murphy (1931) and Leasure (1939) found a sheet of mucus, variable in quantity and distribution according to the physiological state of the animals, overlying the olfactory receptors of mammals. With regard to the gustatory receptors of vertebrates, the situation is more promising. Beidler (1953) has succeeded in developing a flow-system arranged so that the action of saliva can be ruled out of experiments on taste receptors of the rat, and some control over the area of stimulation is also possible.

Chemoreceptors, similar to those in flatworms, occur in closely related phyla. Detailed histological work of Langdon (1895) revealed cells in the skin of *Lumbricus* which had their outer ends elongated into fine hairs and the basal ends consisting of nerve fibers. As is often true, experimental verification of the presumed chemosensory function is lacking. In most of the literature on invertebrates,

the opposite deficiency (i.e., behavioral data without any identification of the sensory areas or end-organs) impairs the significance of the findings. Copeland and Wieman (1924) found that *Nereis* (*Neanthis*) depends primarily upon chemical stimuli in finding food, but the receptors were not located. Similar criticism could be made of the studies of Giersberg (1926) on the octopus, and of Hopkins (1932) on the oyster, to mention only two of many. However, it must be borne in mind that these investigations often were primarily oriented toward other problems.

The arthropods lack a variable secreted layer over the receptors, and bear chemoreceptors on appendages convenient for ablation experiments. The receptors may be on the general body surface, as is thought to be the case with some receptors of *Limulus* which are sensitive to dissolved gases (Waterman and Travis, 1953). Other receptors are found on the mouth parts and nearby appendages of *Limulus* (Barber, 1951).

Doflein (1910) reported that the small antennae were used in responding to chemicals by various decapod crustaceans. Luther (1930) found chemoreceptors on mouth parts, walking legs, and pincers of brachyurans. Physiological confirmation of the studies indicating the presence of chemoreceptors on the antennules of decapods has recently been obtained in our laboratory during studies on chemoreception in the blue crab *Callinectes*, using the electrophysiological technique of Hodgson, Lettvin, and Roeder (1955). Since this technique operates only when a solution of some electrolyte is present over the chemosensory surface, and since sea water is excellent in this capacity, the marine crustacea are now being used to study the basal level of activity of chemoreceptors exposed to their normal covering of sea water. Addition of sucrose and other chemicals to the sea water changes the pattern of afferent impulses, as might be expected. A full report of these results will be presented at a later date.

Among the insects, the location of chemoreceptors is particularly favorable for ablation experiments, and by such techniques the receptor organs have been localized more precisely than for any other class of invertebrates. Chemoreceptors with the lowest thresholds are usually on the antennae (Dethier and Chadwick, 1948), or, in the case of insects having antennae modified for other special functions (e.g., the *Hydrophilidae*), they are on the palpi or their homologues, the tarsi, or on the ovipositor (Frings and Frings, 1949). The experimental advantages of the form and location of insect chemoreceptors are illustrated by a number of studies which have narrowed down the chemosensory areas to a very small number of receptors. Frings and O'Neal (1946) localized the chemoreceptors of horseflies (*Tabanus*) by applying fine glass needles, moistened with sucrose solutions, to individual hairs on the labellum. Responses to chemicals were mediated by medium-sized, thin-walled hairs, or by undiscovered receptors on those hairs. Frings and Frings (1949) later showed that basiconic sensilla were the chemoreceptors on the palpi of several mandibulate insects. Hodgson (1953) found that a very small group (less than 20) of basiconic sensilla on the antennae of the bettle *Laccophilus* were the principal chemoreceptors for a variety of gaseous and liquid chemical stimuli. The only unequivocal experiments localizing a single receptor on the tarsus were recently carried out independently by Lewis (1952) and by Grabowski and Dethier (1954). The latter authors showed that solutions of sucrose, applied to individual trichoid sensilla with micropipettes, elicited the proboscis response from the blowfly, *Phormia*. Staining of the nerves of these sense organs revealed that a maximum of three neurons innervated a single sensory hair. Similar observations have been made on the nerves associated with chemosensory hairs on the labellum (Dethier, pers. commun.). The possibility of stimulating a single sensory end-organ, with so few neurons involved, prompted the first successful electrophysiological studies of insect chemoreceptors, discussed below.

The insects also present some special problems as well as advantages. The influence of the overlying cuticle on the penetration of chemicals to the receptors, while not believed to be a variable in these experiments, is not currently understood, and must be taken into consideration by anyone studying chemoreception in insects. Richards (1952) has provided the only information to date which characterizes the properties of the cuticle over the sense organs. The degree of sclerotization differs in cuticle overlying various types of sense organs, and the cuticle in these regions cannot be assumed to have the same penetration properties as cuticle on other parts of the body. However, the cuticle does not completely block the penetration of water, as might be expected, for the existence of hygroreceptors is well established (Roth and Willis,

1951), and the penetration of water into sensory pegs was directly shown by Slifer (1954).

Histological studies on insect chemoreception are complicated by the notorious difficulties of sectioning the cuticle or applying fixatives or stains through it. The methods used by Grabowski and Dethier (1954) surmount some of these problems. Flies removed from puparia prior to emergence had cuticle still soft enough so that stain penetrated and satisfactory whole mounts showing stained nervous tissues could be prepared. A methacrylate embedding medium, as used by electron microscopists, gave perfect sections with no distortion of the cuticle or hypodermis, at a thickness of one or two microns when cut with an ordinary microtome.

One valid generalization about the location of chemosensory areas would seem to be that they are necessarily situated so as to make possible a comparison of stimulation intensities at two points in the environment. Bonner (1947) has observed that the range within which a single-celled myxamoeba can orient toward a source of diffusing chemicals appears to be limited by the necessity for a stimulus concentration difference of about 3 per cent across the 25-micron diameter of the cell. Comparable calculations are not available for other examples of chemotaxis. The position, shape, and movements of receptor-bearing appendages in many invertebrates undoubtedly have an adaptive significance in extending the distance through which the animals can orient toward a source of diffusing chemicals. Another type of sensory apparatus, different in operation if not in result, is found among snails. Copeland (1918) found that the osphradium is a chemosensory organ of snails, and sampling of stimuli present in different parts of the environment is accomplished by movement of the siphon through which water is drawn toward the stationary osphradium.

Histochemical properties of chemoreceptors

One of the most promising methods of obtaining information about the biochemical specializations of chemoreceptor cells appears to be the application of histochemical techniques. The first observations of this kind were on the distribution of alkaline phosphatase in mammalian tissues. Bourne (1948) noted that alkaline phosphatase is concentrated in the taste buds of the bat and monkey, but concentrated only in epithelium superficial to the taste buds of the rabbit and human being. Olfactory cells and hairs contain alkaline phosphatase, but the olfactory nerve fibers proved to be negative to the stain used; data on the rabbit were exceptional in this regard. A more extensive histochemical survey, later carried out by Baradi and Bourne (1951), demonstrated that, in general, at least seven other enzymes are concentrated in the epithelium lining the folds between taste papillae. All the phosphate-splitting enzymes are concentrated in a few basal cells of the olfactory epithelium. Lipase is absent from the olfactory epithelium, but an esterase is present. Most of these results apply only to the rabbit at the present time. Before basing any general theories on these histochemical results, comparable data would have to be obtained from a study of chemoreceptors in a variety of other animals. Because of the accessibility of the receptors in many invertebrates, they would appear to be favorable material for extending this type of analysis.

Electrophysiological properties

The precision of the techniques for measuring the electrical events which accompany the normal functions of nerves makes these the methods of choice in studying the physiology of chemoreceptors. This objective has been approached by recording afferent discharges in sensory nerve fibers supplying various chemoreceptor cells in vertebrates (Pumphrey, 1935; Euler, Liljestrand, and Zotterman, 1939; Pfaffmann, 1941; Beidler, 1953). However, these studies still leave in some doubt the nature of the response of the primary receptor surface to specific chemical stimuli, and various attempts have been made to apply electrophysiological techniques to the more accessible chemoreceptors of some invertebrate animals. For this purpose, interest has been focused especially upon the arthropods, since, in addition to the convenient location of their receptors, the absence of a mucous layer over the receptor surface constitutes a major experimental advantage.

Barber (1951) recorded action potentials in the gnathobase nerves of *Limulus*. Temperature changes and mechanical stimulation of the gnathobase spines affected the nerve activity recorded, but did not initiate feeding reflexes in whole animals. Homogenates of clam (*Venus*) elicited nerve action potentials which appeared to be the sensory input of the feeding reflex arc. Chapman and Craig (1953) succeeded in recording electrical activity in antennal preparations of various insects. Mechanical, electrical, thermal, or chemical stimulation

with many substances caused a marked and sudden increase in electrical activity. Because of the small size of the insect nerve fibers (of the order of one micron in diameter) it was concluded, however, that individual chemosensory fiber potentials could not be detected with the methods of recording electrical activity then commonly in use. Roys (1954) found that vapors of benzene, toluene, and xylene produced bursts of activity in the antennal nerve of the roach. However, the fact that these vapors produce the same type of activity in an isolated roach ventral nerve cord indicates that no special receptor mechanism is involved. This phenomenon resembles what is generally termed a "common chemical sense," and Roys suggests that such a sensitivity may have preceded more specialized types of chemoreception.

The electrical changes associated with responses of single primary chemoreceptor cells of flies were recorded by Hodgson, Lettvin, and Roeder (1955). The results correlate well with the histological findings of Dethier, discussed above. It is fairly easy in preparations of the labellar chemosensory hairs to recognize the responses of the two receptor cells which innervate the tip of each hair. Sugars, which evoke a "small" spike, elicit a positive feeding response in the intact fly. Salts, acids, and alcohols, which evoke a "large" spike cause a negative or rejection reaction of the intact fly. This is interpreted as evidence of a peripheral discrimination mechanism for "acceptable" and "unacceptable" chemicals, as postulated by Dethier (pers. commun.) on the basis of behavior studies. A detailed description of the results of the electrophysiological studies on labellar chemoreceptors of flies has been presented by Hodgson and Roeder (1955).

It is interesting to compare these observations on a primary chemoreceptor cell with the data based on activity previously recorded from second-order neurons of mammals. By and large, the resemblances outweigh the differences. Concentration/impulse frequency relationships and adaptation curves resemble those found in studies of the sense of taste in mammals (Pfaffmann, 1941; Beidler, 1953). Even some of the levels of stimulus concentration, above which the receptor does not increase its activity, are approximately the same (0.5 *M* sodium chloride, for example) in both insects and mammals. The major differences will be noted in connection with later discussion of the basic mechanisms of excitation.

The stimulus

The enormous variety of chemicals which can stimulate chemoreceptors makes the analysis of the essential properties of the stimulus an extremely difficult problem. Among the more seriously considered characteristics which have been proposed as essential characteristics of stimulating compounds are a particular physical state, various types of molecular structure, and high lipoid solubility.

Physical state

Perhaps the simplest restriction that has been suggested as applying to the stimulating capacity of a chemical is its physical state. At one time, for example, the idea that an animal living underwater might utilize chemoreceptors to orient toward distant sources of stimuli was denied (Nagel, 1894). Stimuli in the gaseous state were believed to be necessary to stimulate the most sensitive chemoreceptors, and the possibility of gases being present in solution appears not to have been considered. The difficulty arose from anthropomorphic connotations of the words "smell" and "taste," and were not entirely removed when numerous investigators demonstrated that receptors connected to olfactory nerves actually functioned in aquatic vertebrates (Parker and Sheldon, 1913; von Frisch, 1924). An experiment directly testing the capacity of the same receptors to respond to a chemical administered in both gas and liquid phases was performed by Hodgson (1953). The beetle *Laccophilus*, which lives in a dual air-water habitat, was exposed to liquid and gaseous chemicals. By ablation experiments, the chemoreceptors were identified as sensilla basiconica on the tips of the antennae and palpi. A very small group of morphologically similar receptors was found to mediate reactions to the same chemicals when administered as gases or liquids. It therefore seems reasonable to conclude that, on a cellular level, the distinction between "olfaction" and "gustation," when based upon the physical state of the stimulus, is meaningless.

Molecular structure

Moncrieff (1946) has provided a thorough review of the voluminous data on this aspect of stimulation. However, as Jahn and Wulff (1950) have pointed out, these data are not susceptible to any

over-all simplifying concept. The most important characteristics of stimuli appear to differ according to the type of compound being tested. In the case of organic compounds, the closest approach to a unifying principle is the correlation between lipoid solubility and stimulating capacity, although exceptions must be made in the case of certain compounds (Dethier and Chadwick, 1950). This concept can be used to explain such data as the increase in stimulating effectiveness of organic compounds with increasing chain-length of the molecules, and the increased stimulating capacity of compounds having functional groups which decrease the water solubility. Experiments yielding results of this type have been performed with flatworms (Cole and Allison, 1930), and with crustaceans and insects from various habitats (Dethier, 1947; Dethier and Chadwick, 1950; Hodgson, 1951). It is further known that in the cases of some compounds (e.g., sugars) there may be a high degree of specificity in their effects (von Frisch, 1934).

The stimulating capacity of electrolytes has been identified primarily as a function of the cations. This has been demonstrated for protozoa (Oliphant, 1938), molluscs (Hopkins, 1932), and insects (Frings, 1946; Hodgson, 1951). By testing various cations in uniform anion combination, it has been possible to demonstrate that the relative effectiveness of the cations parallels the order of ionic mobilities. Exceptions to this rule occur among the divalent salts, however. The order of effectiveness of various anions in uniform cation combination has not been satisfactorily explained (Frings, 1946; Hodgson, 1951).

The similarity of data obtained with many different animals suggests that the basic properties which limit the stimulating capacities of molecules are much the same, regardless of the animal on which they are tested. Mention should be made of one of the few really comparative studies which has been made, in this case comparing the sensitivity of man with that of insects exposed to the same stimuli (Dethier, 1951). The data for homologous aliphatic glycols are typical. When stimulating either the chemoreceptors of the human tongue or the tarsal chemoreceptors of the blowfly, threshold concentrations of glycols decrease logarithmically as the carbon chain is lengthened. This similarity is encouraging, since it indicates that the insect cuticle is not screening out particular categories of compounds which could impair the general significance of the insect studies.

Modalities

From studies on chemicals that stimulate the vertebrate taste receptors, there has emerged the idea of four basic categories of taste sensations, and four basic types of chemical stimulants. These are described as the sensations of "salty," "sour," "bitter," and "sweet." The significance of this idea is evident from Beidler's (1953) statement: "This is perhaps the most important of all concepts upon which our present theories of taste are constructed." Considerable evidence supports the theory as applied to mammals (Beidler, 1953).

The question of concern here is whether the properties of stimuli responsible for the grouping into modalities for mammals are fundamental in the sense of being likewise important for other animals. Difficulty in judging the evidence on this point arises from the fact that most experiments on invertebrates have been designed to test only a limited number of chemicals, almost invariably the same ones associated with the classic modalities. Bauer (1938) found by conditioning experiments that the beetle *Hydrous* could differentiate between sugars, HCl, NaCl, and quinine, and the data were interpreted as supporting the theory of four taste modalities for insects. Ritter (1936) reported that acids stimulated only the labial palpi of *Hydrous*, providing a parallel with the specialization of different receptor groups noted in mammals. However, Hodgson (1953) presented evidence that differences in thresholds of the receptor groups could explain these results, and the influence of changing concentrations of stimuli upon discrimination is still largely unexplored among invertebrates. Frings (1951), on the basis of comparative studies of taste thresholds with six species of animals and many stimulating compounds has discarded the idea of four primary taste qualities and formulated an entirely different concept, the "taste-spectrum" hypothesis. He suggests that the cells with lowest thresholds, when stimulated, produce the sensation "sweet," and the stimulation of the maximum number of receptors results in the sensation "sour." A spectrum of gradual intermediates is postulated between these extremes. This concept appears to explain many data which have been very difficult to fit into any previous theory, an example being the shift in modality of

sensation with changing concentrations of a stimulus. It is interesting to note that Fring's hypothesis comes at a time when histochemical studies have also led to questioning of the classic modality concept (Baradi and Bourne, 1951). It would be interesting to test on the invertebrates the various drugs which block perception of particular modalities of stimuli applied to chemoreceptors of mammals. A great deal more work needs to be done on this topic before the general significance of the taste modalities can be known. Attempts to reduce so-called "olfactory" stimuli to modalities have failed (Jahn and Wulff, 1950).

The reactions between the stimulus and the receptor cell

Many ideas concerning the mechanism of chemoreceptor stimulation have been advanced, only to be found untestable or in disagreement with the facts. The most pertinent data at the moment are derived from electrophysiological studies of primary chemoreceptors or closely associated neurons, and from analyzing changes in chemoreceptor function after the administration of drugs which have known effects on metabolism. It would be premature to speculate on the precise relationship between the electrically detectable symptoms of receptor activity and the metabolic steps in excitation. Work on other sense receptors suggests that the initial step in excitation may be either very closely linked to the electrical events recorded (e.g. in hearing; Davis, 1954) or, in other cases, may involve several metabolic steps (e.g. in vision; Wald, 1954).

Whatever fundamental mechanisms initiate impulses from the chemoreceptor, they do not depend exclusively upon the action of externally applied chemical stimuli. Pfaffmann (1941) found that gustatory receptors of the cat usually discharge spontaneously at a low frequency even when no chemical stimuli are being applied. Similar observations have been made on mammalian olfactory preparations (Walsh, 1953), insect chemoreceptors (Hodgson and Roeder, 1954), and a wide variety of other neurological preparations (Roeder, 1955). Sensory systems exhibiting this characteristic are unusually well adapted for perception of extremely minute changes in the environment (Roeder, 1955), and it is undoubtedly not a simple matter of chance that chemoreceptors fall into this category. The problem, then, is to determine the mechanisms that increase the frequency of discharge of the chemoreceptor.

The data indicate that at least two types of excitatory mechanisms exist among the chemoreceptors which have been studied with electrophysiological techniques. Beidler (1953) noted that acids and salts stimulate rapidly and give rise to a very large response from chemoreceptors on the tongue of the rat. All of the sugars investigated with this preparation were found to stimulate activity more slowly than acids and salts, and the final magnitude of the sugar response is smaller. Essentially the same thing has been found in direct measurements of electrical activity from the primary chemoreceptors of flies (Hodgson, Lettvin, and Roeder, 1955). Receptors responding to sugars characteristically discharge later after stimulation, have a lower frequency of discharge, and generally a more irregular discharge frequency than the receptors responding to salts, acids, or alcohols. The adaptation curves and relations between concentration and frequency of receptor response, though tending in the same direction, are strikingly less variable and more easily predicted with salt stimulation than with sugar effects. These observations, plus the mutually exclusive receptors for sugars and salts and the known reaction specificities of many sugars, support the hypothesis that sugars activate chemoreceptors in a very different way from salts, and possibly other chemicals. More precise receptor specificities might be interpreted as variations on one or the other of two basic types of excitatory processes. For example, when special acid-sensitive fibers, or acid and quinine-sensitive fibers have been found, it is interesting to note the presence of some fibers responding to acid and sodium chloride (Pfaffmann, 1941). This would seem to be most simply understood as an evolutionary divergence of variously specialized chemoreceptors from a single original cell type. Experiments on the effects of enzyme inhibitors, temperature, and other influences which might have differential effects on two or more types of excitatory systems could be used to determine whether this concept is valid.

What could be the essential difference between the two types of excitatory processes postulated? Beidler has recently offered an interesting theory of taste stimulation based on responses of mammalian chemoreceptors to sodium salts (Beidler,

1954). Taking the speed, reversibility, and other characteristics of the excitation process into account, he proposes that the initial reaction which ultimately leads to stimulation of the receptor is a loose binding of ions of the chemical stimulus to some polyelectrolyte located on or near the surface of the receptor. The changes in free energy calculated for the process and its temperature independence are used as evidence that enzymatic reactions are probably not directly involved in the initial steps of excitation. From data based on behavioral studies of insect chemoreception it has been reasoned that "the mechanism of sugar stimulation may involve a specific chemical process in contrast to salts, acids, alcohols, etc., which appear to be acting via a non-specific mechanism" (Dethier, 1953). By putting these two suggestions together, there might be a clue to a fundamental difference between the two postulated categories of excitation mechanisms: the sugars most likely being involved in enzyme-mediated reactions at unknown locations, while other chemicals are loosely bound through non-enzymatic mechanisms at the receptor surface.

The electrophysiological data on insect chemoreceptors do not, however, entirely agree with the evidence upon which Beidler (1954) constructs his hypothesis. It is true that the time interval between application of a salt and onset of the receptor's response is very short. In fact, in the labellar chemoreceptors of flies the latency of response may be as short as 10 milliseconds, or about half of the shortest intervals measured when recording from second-order neurons in vertebrates. This discrepancy undoubtedly arises from the fact that in the insect preparations activity is being studied closer to the sensitive receptor surface. The insect chemoreceptor is markedly influenced by temperature, however, for the frequency of impulses in response to salt stimulation changes with as little as a one-tenth degree (C.) fluctuation in temperature. Therefore, it cannot be argued from the data on insects that enzymatic processes are necessarily ruled out of the initial step in salt stimulation (Hodgson, Lettvin, and Roeder, 1955). It should be noted also that temperature has a significant influence on the thresholds of insect behavioral responses to chemicals (Frings and Cox, 1954), as would be expected from the electrophysiological data.

Experiments on invertebrates have contributed very little to pharmacological investigations of the metabolism of chemoreceptors. The possible use of drugs in studying the modality problem with invertebrates has already been mentioned. Additional possibilities stem from the pharmacological studies on carotid chemoreceptors in mammals. Whether or not the carotid chemoreceptors, stimulated by respiratory gases, have more than a semantic resemblance to any chemoreceptors in invertebrates remains to be seen, but studies on carotid chemoreceptors have prompted some recent work on gustatory receptors of vertebrates. It has been proposed on the basis of findings critically evaluated by Daly (1954), Douglas (1954), and Liljestrand (1954), that acetylcholine plays a fundamental role in the initiation of impulses recorded in the carotid nerve. The phenomenon is complicated by the histological picture of the carotid body, for a single nerve fiber can supply more than one type of receptor cell and electrophysiological studies of activity from single carotid chemoreceptor cells seem to be impossible (de Castro, 1951; Daly, 1954; de Kock, 1954). However, in extending these experiments to new material, Landgren, Liljestrand, and Zotterman (1954) found that acetylcholine and anti-cholinesterases cause an increase in the firing of taste nerve fibers of the frog. They interpreted this as evidence that acetylcholine is concerned with the initiation of impulses in the gustatory chemoreceptors. This raises an interesting problem for comparative study using chemoreceptors of invertebrates, and especially with insects. Nerve preparations from the latter group of animals have proved to be astonishingly insensitive to externally applied acetylcholine, and the role of acetylcholine in the insect nervous system is unknown (Roeder, 1953). Acetylcholine or various anti-cholinesterases, applied singly or in combination to labellar chemoreceptors of flies, have thus far failed to produce any change in the pattern of receptor activity as measured electrophysiologically (Hodgson, unpub.).

The integrated response to chemical stimulation

The motor responses which are initially triggered by impulses from chemoreceptors vary according to other factors within the organism. Information about these factors is often pertinent to the interests of both physiologists and ecologists. The

effect of a fairly generalized influence, such as the amount of food or water that has been recently ingested, is usually difficult to assess. There is little to suggest the actual mechanisms that are involved, at least in the literature on invertebrate animals. A start in this direction has been made in studies of mammals.

Richter's (1943) classic experiments demonstrated that rats with dietary or endocrine deficiencies selectively consume materials containing the deficient components. These studies have recently been extended and discussed by Soulairac (1947), Lepkovsky (1948), and Young (1948). Pfaffmann and Bare (1950), using electrophysiological techniques, compared the gustatory thresholds for salt in normal and adrenalectomized (salt-deficient) rats. They concluded that the lowered preference threshold for salt following adrenalectomy was not due to a change in the taste receptors. Relatively little is known about the relations between chemosensory thresholds, diet selection, and nutritive requirements of invertebrates, and practically all of the existing data concern insects. Hassett, Gans, and Dethier (1950) found no clear relationship between nutritive values and taste thresholds of carbohydrates for the blowfly. Insects apparently differ from the rat in lacking a tendency toward constant intake of food. Wykes (1952) and Dethier and Rhoades (1954) found that carbohydrate requirements apparently do not regulate intake of sugars by bees or blowflies. Not enough is known about these problems in other invertebrate groups to permit tracing the phylogeny of regulatory mechanisms.

The central nervous system is the major site of inhibition of behavioral responses when insect chemoreceptors are exposed to various "unacceptable" chemicals, as shown by Dethier (1953). Unacceptable compounds terminate the response to sucrose even when they are applied to tarsal chemoreceptors on a leg other than the leg exposed to sucrose. The central nervous system can also "amplify" the effects of impulses coming from the chemoreceptors. For example, the response of a fly to stimulation of one of its chemosensory hairs may vary from no detectable reaction to a whole complex of motor activities, including repeated proboscis extensions, leg movements, abdominal flexions, etc. The actual response obtained in any one test may vary with the nutritional state of the fly. The extent of the "amplification" factor in the central nervous system of a hungry fly can be appreciated from the fact that the whole complex pattern of motor responses, involving most of the insect's appendages and many other parts, can be initiated by stimulating a single chemosensory hair. If present ideas are correct, the trigger mechanism can be further narrowed down to only a slight increase in the frequency of impulses coming from one of the two chemoreceptor cells associated with the chemosensory hair.

CONCLUSION

The problems concerning invertebrate chemoreception are, on a cellular level, essentially the same problems that arise in attempting to understand chemoreception in any animal. From an ecological standpoint, however, the present deficiencies in our knowledge of chemoreception are much more seriously felt in studies of the invertebrates than in work on the vertebrates. General aspects of chemoreception about which information is currently needed include: (1) the basis for the selectivity of behavioral responses to chemical stimuli, (2) the fundamental excitation processes in chemoreceptors, and (3) the mechanisms by which impulses from chemoreceptors initiate integrated patterns of motor activity. The invertebrate animals can provide experimental material which is especially favorable for studying various aspects of these problems.

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THE PHYSIOLOGY AND HISTOLOGY OF THE CONTACT CHEMORECEPTORS OF THE BLOWFLY

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INTRODUCTION

UNTIL THE beginning of the twentieth century the identification of chemoreceptors in insects was based solely upon morphological criteria. Localization on a suitable area of the body and conformity to some preconception regarding the probable appearance of a chemoreceptor governed the assignment of chemosensory functions to any sensillum (a simple sense organ consisting of a cuticular part, one or more sense cells, and associated chitinogenous cells). Accordingly, of the nine structurally different types of sensilla found in insects, those possessing an extremely thin cuticular covering were considered to be chemosensory. On this basis, sensilla basiconica (pegs) and some sensilla trichodea (setae) have come to be regarded as typically gustatory.

Those experimental studies which had been undertaken consisted of observations of behavioral responses following stimulation of intact appendages studded with populations of miscellaneous sensilla. Such studies revealed that contact chemoreceptors were located on the antennae of bees and ants, the mouthparts or adjacent surfaces of the preoral cavities of many species, the distal segments of the legs of bees, flies, and Lepidoptera, and the ovipositor of *Gryllus* and certain parasitic Hymenoptera (Dethier and Chadwick, 1947; Frings and Frings, 1949). Although this gross experimental approach was also rewarded with the accumulation of much information concerning the characteristics of the adequate stimulus, thresholds of acceptance and rejection, adaptation, and summation, the disadvantage of working with a multitude of receptors was clearly reflected in the difficulties of interpreting results.

These difficulties could be overcome only by indisputable identification and isolation of sensilla. Minnich (1926) became the first person to stimulate a single chemoreceptive organ when he applied sugar to one sensillum trichodeum on the labellum of *Phormia regina*. Strangely enough, few workers appreciated the significance of his accomplishment, although Frings and O'Neal (1946) did attempt to stimulate single receptors on the labellum of the horsefly *Tabanus sulcifrons*. With the exception of additional similar studies of several species of insects by Frings and Frings (1949), no further work of this nature was attempted until Lewis (1952, 1953, 1954) succeeded in identifying and stimulating single chemoreceptors on the tarsi of the blowfly *Protophormia terra-novae* and Grabowski and Dethier (1954) completed similar experiments with *Phormia regina*. Since then the receptors in the housefly, *Musca domestica*, have also been identified (Lewis, 1954; Dethier, 1955). In each case cited above the sense organ involved was a sensillum trichodeum.

The positive identification of chemoreceptors makes possible more precise analyses of contact chemoreception and is manifestly a prerequisite to any understanding of the process. Thus far, such positive identification has been made only in the species of flies mentioned below. The present discussion is concerned primarily with a physiological study of individual sensilla located on the tarsi and labellum of *Phormia regina*. A detailed account of the histology is given by way of background. Comparable, though less extensive, studies have been made of *Protophormia terra-novae*, *Musca domestica*, *Calliphora erythrocephala*, *C. vomitoria*, and *Drosophila melanogaster*. No essential differences among these species were detected.

For histological examination tissues were fixed either in aqueous or in alcoholic Bouin's solution, double-embedded by Peterfi's (1921) method, sectioned at 5 microns, and stained with one of the following preparations: Heidenhain's iron hematoxylin and eosin, Delafield's hematoxylin and eosin, Mallory's triple stain (in this instance tissues were fixed in Zenker's fluid), protargol (Bodian, 1936), or silver (Romanes, 1946; Samuel, 1953). Whole mounts were stained with methylene blue (cf. Grabowski and Dethier, 1954). In addition,

teased living tissues were examined with a phase contrast microscope. Physiological tests were conducted on flies which were fastened by the wings to paraffin blocks on applicator sticks. With the exception of the interpseudotracheal papillae, all receptor organs described in the following sections were identified as to function by direct individual stimulation. The criterion of response in each case was a behavioral one.

HISTOLOGY

Labellar hairs

The lobes of the labellum of all flies studied bear on their aboral surfaces two structurally different types of hairs. One, an acutely pointed, straight, rather heavily pigmented, socketed seta with a single central, thick-walled lumen, is not sensitive to chemical stimulation, and hence is of no further concern in this study. The other is a relatively blunt-tipped, curved, light-colored, thin-walled socketed seta with two central lumina. It is identical in all major respects to the tarsal receptors described by Lewis and by Grabowski and Dethier. These hairs are distributed on the laterodorsal or aboral surfaces of the labellar lobes, and are arranged more or less in several concentric rows. The dorsal ones, that is, those farthest from the edge of the oral surface, are the longest and are the first hairs to touch the substrate when the proboscis is extended. They measure, on the average, 300 microns. Most ventral and nearest to the oral surface are short hairs which are 30 microns in length. Intermediate in position is a series of hairs which vary in length from 150 to 200 microns. Altogether there are approximately 150 hairs with two lumina on the labellum. Contrary to the findings of Frings and O'Neal (1946) with *Tabanus sulcifrons* and Frings and Frings (1949) with *P. regina* and *M. domestica*, all of the double-walled hairs, regardless of length, in the last two species are sensitive to stimulation by sucrose.

The following description of one of the 300 micron hairs may be taken as representative of the typical chemoreceptive hair of the labellum. In contrast to the simple tactile hairs, it is generally gracefully curved. A cross section (Fig. 1, C) clearly shows the outline of longitudinal fluting on the exterior. A hair (Fig. 2) which is 300 microns long is 9 microns in diameter at the base and is mounted in a socket which is 12 microns in diameter. At its tip the hair is 1.5 microns in diameter. The tip is surmounted by a small papilla approximately 0.75 microns high (Fig. 17). This protuberance stains black with silver, while the remainder of the hair remains clear. In living preparation the protuberance is highly refractile. Its shape is readily altered by treatment with such solvents as water, alcohol, and xylene. In some instances it appears to shatter into two spinous protuberances. These observations suggest that it differs from the rest of the cuticle of the hair at least in softness and flexibility. A papilla with similar staining properties was also observed on certain tarsal hairs of lepidoptera by Eltringham (1933). Within the hair are two lumina. One of these was erroneously interpreted by early histologists (Kraepelin, 1883; Hewitt, 1907) as being a longitudinal groove exposed throughout its length to the air.

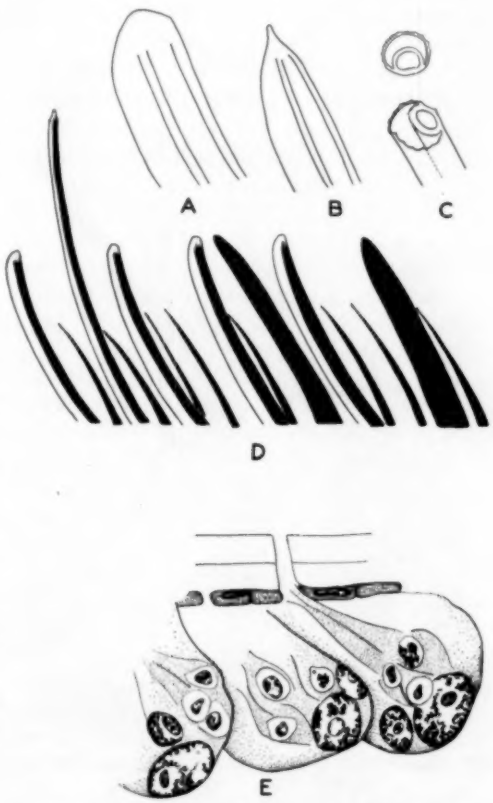


FIG. 1. TYPES AND STRUCTURE OF TARSAL CHEMOSENSORY HAIRS

A, A-type tarsal chemosensory hair; B, B-type tarsal chemosensory hair; C, cross-sections of chemosensory hairs; D, profile showing relationship of two types of chemosensory hairs and neighboring spines on the ventral tarsal surface; E, types of cells associated with the A-type chemosensory hairs of *Phormia regina*.

Tinbergen (1939) correctly described two cavities in the hairs of *Calliphora erythrocephala*.

At a point 10 microns from the base of the hair the lumen of the thin-walled cavity is 2 microns in diameter; that of the thick-walled cavity, 1.5 microns. When a hair is immersed directly in xylene, Brownian movement can be observed in the thin-walled lumen but not in the other. Hairs in living preparations which are transferred rapidly from water to absolute alcohol to xylene develop small bubbles which are trapped in the thick-walled cavity. Localized pressure can cause these bubbles to move within the cavity but not from one cavity to the other. These experiments confirm the evidence offered by histological sections that the two lumina are separate and distinct.

Beneath each hair is suspended a conspicuous subhypodermal sac of cells (Fig. 2). This sac varies from 25 to 30 microns in diameter in the case of the longest hairs. It consists of five large cells: the trichogen, the tormogen, and three bipolar neurons. In addition there may be one or more tracheolar cells together with occasional neurilemma cells. It was the presence of these accessory cells which led some investigators to ascribe to each sensillum a large number of neural cells. The neurilemma cells are small, seldom exceeding 4 microns in diameter. Tracheolar cells are of the same order of magnitude. Associated with the tracheolar cells is a loose dichotomy of tracheoles which are 0.75 to 1.0 microns in diameter. Arranged as a basketwork around the entire cellular sac and its neighbors beneath the other hairs is a tissue containing fine granules of dark yellow to brown pigment. Since this pigment is somewhat soluble in ether, it is not seen in celloidin-embedded preparations. It is conspicuous in the labellum of *Phormia*, *Protophormia*, *Calliphora*, and *Musca*. Since the pigment is not contained within the neurons nor associated at all with the tarsal sensilla, it is unlikely that it is in any way concerned with the process of chemoreception. Leydig (1859) had noticed this network in *Calliphora*, *Musca*, and *Sarcophaga* and realized that it was not nervous tissue. Kraepelin (1883) mistook it for a nerve net. Lowne (1890–95) noticed the pigment but incorrectly assigned it to the neural cells. Hewitt (1907) illustrated the position of the pigment-containing cells correctly.

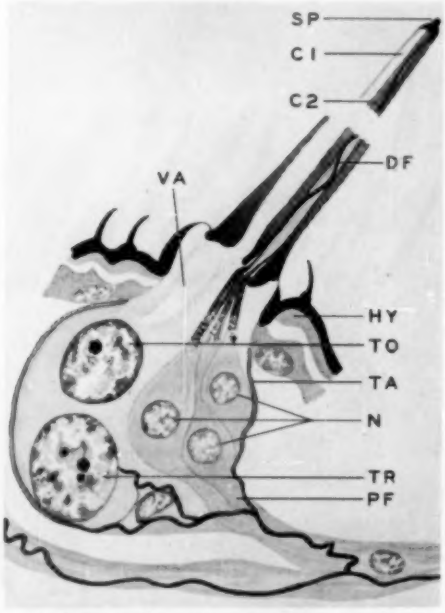


FIG. 2. TYPICAL CHEMOSENSORY HAIR OF *PHORMIA* (PIGMENT-CELL LAYER OMITTED)

The following symbols are applicable to all the following figures. HY, hypodermis; DF, distal fibers; SB, sensillum basiconicum; PF, proximal fibers; N, neurons; TR, trichogen; TO, tormogen; BP, bipolar neuron; C1, thin-walled cavity; C2, thick-walled cavity; TA, tracheole; P, pigment cell layer; CS, chemosensory hair; PS, pseudotrachea; IP, interpseudotracheal papilla; VA, vacuole; SP, sensory papilla.

The largest of the sac cells, the trichogen, is 15–17 microns in diameter and 30 microns long. It contains a giant nucleus 8–10 microns in diameter. With most stains the chromatin is coarsely and irregularly granular. In living cells the nucleus appears non-granular. With vital stains a small nucleolus can be seen. With usual methods of staining, the cytoplasm is finely, evenly granular, without obvious inclusions. Its appearance in the living state is similar. It does, however, possess a conspicuous vacuole (Fig. 8, VA). This extends at least into the subsetal pocket, whence it is continuous with both lumina of the hair. These features, the large nucleus and vacuole, in company with the alleged groove in the hair, misled Kraepelin (1883) into believing that the hair was secretory. Leydig (1859) decided that it was a tactile sense organ.

The second largest cell is the tormogen. Its diameter is 8 microns; its length, approximately 15 microns. The long diameter of its nucleus is 10 microns; the short diameter, 7 microns. It does not differ in any major respects from the trichogen except that it lacks a conspicuous vacuole.

The remaining three cells within the sac are neurons. They are the only cells of the bundle which stain darkly with methylene blue (Fig. 20). One invariably stains less darkly than its companions. All three are approximately equal in size. The diameter is 7 to 9 microns; the length, 22 microns; the diameter of the nucleus, 4 to 6 microns. The cytoplasm stains more deeply than that of the non-neural cells and in living tissue appears more granular. With methylene blue it appears very coarsely granular. The nuclei stain less deeply than those of other cells. Each neuron possesses a conspicuous distal fiber (Fig. 8, DF). The three traverse a distance of 15 microns to the base of the hair. At this point the combined diameter is approximately 2 microns. In living tissue the diameter is from 3 to 4 microns. A single fiber in fixed material varies from 0.5 to 1 micron in diameter. The three fibers proceed independently from the cell bodies but come into proximity near the base of the socket (Fig. 11). Here there may be a pronounced swelling (cf. Grabowski and Dethier, 1954). Beyond this point the fate of one fiber is unknown. It has not been traced past the region of the subsetal pocket. There is no clear indication that it terminates in the region of the socket in the manner described by Grabowski and Dethier (1954). The remaining two fibers continue to the base of the hair. Just before entering the lumen each fiber is abruptly reduced in diameter (Fig. 16). Two thin strands pass up the lumen of the thick-walled part of the hair (Fig. 16) and continue to the extreme end, where they become associated with the deeply staining papilla (cf. Eltringham, 1933). More exact relationships cannot be ascertained. At this point the wall of the hair is, at most, 0.1 to 0.2 micron thick. Each strand is 0.1 micron in diameter. Whether these strands are the distal fibers extended into the lumen or represent a terminal apparatus of different origin (cf. Snodgrass, 1935, p. 520) remains an unanswered question. In any event, the strand reacts toward silver in the same manner as do the distal fibers. Furthermore, as will be shown later, it transmits excitation. Since it appears that the lumen of the hair is continuous with the vacuole of the trichogen, the terminal strands are presumably bathed in whatever fluid may fill the vacuole. When the tip of the hair is amputated, no bubble of fluid appears spontaneously at the cut end; however, if this end is immersed in water or physiological saline, a rather viscous drop gradually forms. It is not possible to determine from which of the two lumina the drop emerges.

It is abundantly clear that no fibers enter the lumen of the thin-walled section of the hair.

Each neuron possesses three distinct proximal fibers, each of which is from 0.75 to 1 micron in diameter. The combined diameter is 2 microns in fixed material, 4 microns in living material. Each can be traced as an individual fiber for a distance of 30 to 40 microns before losing its identity. Beyond this point fibers from neighboring sacs join the group to form, in company with fibers from all other sensory hairs on the aboral surface of the labellum, an extensive subhypodermal plexus which eventually constitutes part of the labial nerve. There is no evidence that any synapses occur before the labial nerve enters the subesophageal ganglion.

Tarsal Hairs

Chemoreceptive hairs on the legs conform in nearly all respects to the description just given (Figs. 1 and 14). They have been described in considerable detail by Grabowski and Dethier (1954), Lewis (1954), and Dethier (1955). Detailed descriptions of similar hairs on the tarsi of *C. erythrocephala* have been given by Tinbergen (1939).

There are four distinct types of thin-walled hairs with double lumina. Of these types B, C, and D differ in length only. The longest, D, measuring from 145 to 265 microns, have not yet been proven to be sensitive to chemicals. Type A differs from all others in possessing an extremely blunt tip and a greater diameter in proportion to its length (Fig. 1). The papilla on the end differs somewhat in shape from those on other hairs. The tips of all types tend to stain heavily with methylene blue.

As with the labellar hairs, each tarsal hair is equipped with a sac of cells (Fig. 1). There are, however, no pigment cells; otherwise the cytological details are the same. The principal cellular components include a trichogen, tormogen, and three bipolar neurons. One of the latter stains only faintly with methylene blue. The distal fibers of two cells clearly enter the thick-walled cavity of the hair (cf. Tinbergen, 1939) (Fig. 19). The termination of the third has not been located. There is some doubt as to whether it is actually inserted on the socket (cf. Grabowski and Dethier, 1954). Within the lumen of the hair the two fibers can be seen extending all the way to the end, where they become associated with the deeply staining papilla.

Some idea of the dimensions of the receptor parts can be gained from the following measurements of an average type C sensillum of *Phormia* (Fig. 14): hair length, 125 microns; diameter at base, 2; thickness of wall at tip, 0.1; diameter of cellular sac, 10 to 13; length of sac, 30; length of trichogen, 20; diameter of trichogen, 8; long diameter of nucleus, 7; short diameter of nucleus, 5; diameter of tormogen, 5; long diameter of tormogen nucleus, 6; short diameter of tormogen nucleus, 4; diameter of neuron, 4 to 5; diameter of neuron nucleus, 2 to 3; length of distal fiber from cell body to base of hair, 0.7; combined diameter of all distal fibers in fixed material, 1.5, and in living material, 2 to 3.

For the sake of comparison the following dimensions of the single bipolar neuron which innervates a large tactile spine (Fig. 14) are listed: diameter of neuron, 8 to 9 microns; length, 15 to 20; diameter of nucleus, 5; total length of distal fiber from cell body to insertion at base of spine, 20 to 30; diameter, 1 to 2; diameter of proximal fiber in fixed material, 1.5 to 2, and in teased living material, approximately 4.

Interpseudotracheal papillae

Projecting through the syndesmoses between the pseudotracheal and interpseudotracheal plates of the oral surface of the labellum there are from 135 to 189 minute sensilla basiconica. With the exception of Lowne (1890–95), who thought that the papillae were the orifices of labial glands, early workers (Künckel d'Herculais, 1879; Künckel and Gazagnaire, 1881; Kraepelin, 1882, 1883; vom Rath, 1888; and Hewitt, 1907) guessed the structures to be gustatory. Graham-Smith (1930) and Hertweck (1931) followed this lead, although the former suggested an additional tactile function.

The so-called papilla is a sensillum basiconicum which is 10 microns long, 5 microns in diameter at the base, and 2.5 microns in diameter at the tip (Fig. 21). At the tip, the cuticle is 0.1 micron or less in thickness. The cuticular portion of the sensillum consists of a peg surmounting a broader base which consists of two sclerotized annular areas separated by thinner unpigmented cuticle. The basal ring is two to three times as wide as the other. Except at its tip the peg is heavily sclerotized. The internal cavity shows one expansion at the level of the narrow ring and another within the peg (Fig. 23). The terminal nerve strand extends to the tip, which is extraordinarily transparent. Although the tip gives every appearance of the opening of a duct leading to a group of subhypodermal cells, the impression is false. Leydig, Künckel, Künckel and Gazagnaire, Kraepelin, and vom Rath clearly described and illustrated the relations between the distal nerve fibers and the cuticular tip, but Hewitt (1907) and Graham-Smith (1930) apparently followed the false lead of Lowne in describing an aperture and duct.

The neurons lie in a subhypodermal group 30 to 40 microns distant from the cuticle. The cell group is from 15 to 20 microns long and 6 to 10 in diameter. There appear to be only two neurons, although the possible existence of a third cannot be definitely excluded at this time. No other cells stain readily with methylene blue, and only two distinct fibers can be seen in silver preparations (Fig. 22). The short diameter of each neuron nucleus is 2.5 to 3 microns; the long diameter, 5 to 6. The combined fiber diameter at the base of the peg is 0.75 to 1 micron. A single distal fiber is 0.5 micron in diameter. There are invariably two larger cells associated with the neurons. Their nuclei are approximately 6 microns in diameter. These are quite probably trichogen and tormogen. Folds of hypodermis from the interpseudotracheal cuticle are frequently appressed closely to the distal fibers, so that extra nuclei may be associated with them. Proximal fibers from the nerve cell bodies of all the sensilla join to form a branch of the labial nerve, and together with the branches from the aboral hairs go to the subesophageal ganglion apparently without synapsing.

STIMULATION OF LABELLAR AND TARSAL HAIRS

Site of action

As Minnich (1926) showed for the labellum and Lewis (1952) and Grabowski and Dethier (1954) for the legs, some chemosensory hairs can be stimulated by sugar. When sucrose is applied, the fly responds by extending its proboscis. However, not all parts of a hair are sensitive. This can be shown by topical application of minute drops. If a small drop of solution consisting of 0.1 *M* sucrose and 1 *M* propanol is placed upon a fine sewing needle, which is hydrophobic when new, the alcohol soon begins to evaporate. As a result the drop decreases in size and increases in sucrose concentration. The smaller drop can now be coaxed on to the base of a hair. On larger hairs it can gradually be rolled up the shaft. At no point in this procedure does the fly respond until the drop reaches the tip of the hair.

It makes little difference whether the drop is rolled along the external surface of the thick-walled cavity or that of the thin-walled cavity. Furthermore, if the tip of the hair is amputated, the hair loses permanently its sensitivity to sugar and water. Clearly, it is at the tip that the effective portion of the receptor organ lies. In view of the close association of the distal fibers with a terminal papilla of unique properties this result is not surprising. Since the same result has been obtained with the large and medium-sized labellar hairs as well as with the C hairs of the tarsus and the B hairs of the tibia, it is probably fair to assume that all of the sensitive hairs in these areas behave similarly.

Adequate stimulus for sugar receptors

It has been shown by Hassett, Dethier, and Gans (1950) that the tarsi of *P. regina* are sensitive in varying degrees to at least eighteen sugars and are insensitive to straight-chain polyhydric alcohols. With few exceptions these results compared favorably with threshold values for the tarsi and mouthparts of *Calliphora erythrocephala* (Haslinger, 1935) and the tarsi of the butterfly *Pyrameis atalanta* (Weis, 1930). For the honeybee (Vogel, 1931; von Frisch, 1935) and the ants *Lasius niger*, *Myrmica rubra*, and *M. rubida* (Schmidt, 1938), fewer carbohydrates are acceptable. Nevertheless, the order of effectiveness of those sugars which are stimulating is generally the same for all species. One of the questions raised by these data is whether or not any single receptor is sensitive to all of the carbohydrates to which the insect as a whole responds. Tests with mixtures of sugars (von Frisch, 1935; Bauer, 1938; Wykes, 1952) strongly indicated that insects could not readily distinguish one sugar from another and that therefore there probably were not specific receptors for different sugars. Experiments with single labellar and tarsal hairs of *P. regina* and *M. domestica* have confirmed this conclusion.

In all, 75 carbohydrates, 8 polyhydric alcohols, 53 amino acids, and 18 monobasic and dibasic acids have been applied to several individual hairs in tests to determine which kinds of compounds can elicit an extension of the proboscis. The results of these tests (with the exception of those with the acids, which were uniformly negative), together with threshold data obtained by stimulating entire tarsi, are listed in Table 1. Because single hairs adapt extremely rapidly, it is somewhat difficult to obtain meaningful threshold values for large numbers of compounds acting on a single hair; hence, in these cases each compound was applied at maximum concentration and designated simply as effective (+) or ineffective (−). On this basis, no single hair was found either on the labellum or tarsi which was sensitive to every compound to which the insect as a whole was sensitive. Yet every hair was sensitive to the same compounds. In other words, there are not specific hairs for specific sugars.

The failure of a single hair to mediate a response to every sugar to which the insect is sensitive is not entirely surprising when one considers that spatial summation of many receptors may be required to mediate responses to some compounds which are so poorly stimulating that inordinately high concentrations are required. In some such cases solubility limitations thwart all attempts to apply to a single hair the requisite concentration. A glance at Table 1 will reveal that the compounds which fail to stimulate a single hair sufficiently to provoke a response are usually the compounds for which the threshold value is very high (e.g., mannose, lyxose, cellobiose).

Here, then, is a sensillum which can be stimulated by a limited variety of carbohydrates. As far as can be determined, carbohydrates are the only compounds, with the possible exception of some salts in low concentrations, which are effective in initiating a proboscis extension. By way of contrast it should be noted that stimulation of the tarsi of the butterfly *Pyrameis atalanta* Linn. with 2 *M* NaCl or 0.1 *M* quinine hydrochloride elicits extension of the proboscis (Minnich, 1922). For the flies this is not true. Furthermore, neither acids nor polyhydric alcohols, with the exception of inositol, are effective. A triose (glyceraldehyde), a tetrose (erythrose), and the related tartaric acids are likewise ineffective. No hydroxyaldehyde or glycol is effective. These facts, especially the isolated effectiveness of inositol among all the polyhydroxy compounds, suggest that a cyclic molecule is, if not essential for stimulation, at least preferred. The ineffectiveness of a triose and tetrose on the one hand and heptoses and octoses on the other hand indicates, moreover, that there is an optimum chain length. This limitation appears to hold for all insects tested. On the other hand, the isolated effectiveness of inositol among all the polyhydric alcohols is a feature of the physiology of *Phormia*, *Musca*, and *Apis*. Certain

TABLE 1

Effectiveness of various carbohydrates in stimulating single labellar hairs and groups of tarsal hairs in Phormia regina

Compounds which elicit proboscis extension when applied to single hairs are designated (+). For compounds which are effective on entire tarsi, the molar concentration which causes 50% of the flies to accept is given when known. Starred values are from Hassett, Dethier, and Gans (1950). Compounds designated with (−) are non-stimulating at all concentrations; those designated with (‡) are effective on groups of labellar hairs but not on single hairs.

Compound	Single Hair	Tarsi
Triose		
DL-glyceraldehyde	−	−
Tetroses		
D-erythrose	−	−
L-erythrose	−	−
Pentoses		
L-fucose	+	0.087*
D-arabinose	+	0.144*
L-arabinose	+	0.536*
D-xylose	+	0.440*
L-xylose	+	0.337*
D-ribose	−	8.99*
D-lyxose‡	−	42.27*
ribulose	−	−
L-rhamnose	−	−
2-desoxyribose	−	−
Hexoses		
D-fructose	+	0.0058*
D-glucose	+	0.132*
L-sorbose	+	0.140*
D-galactose	+	0.50*
D-mannose‡	−	7.59*
D-tagatose	−	−
D-gulose	−	−
idose	−	−
D-altrose	−	−
Heptoses		
D-α-glucoheptose	−	−
D-gluco-D-guloheptose	−	−
Octose		
D-gluco-L-gala-octose	−	−
Disaccharides		
sucrose	+	0.0098*
turanose	+	0.011
D-maltose	+	0.0043*
D-trehalose	+	0.133*
cellobiose‡	−	5.01*
lactose	−	−
melibiose	−	−
invert sugar	+	0.0062
equimolar glucose-fructose mixture	+	0.0078
Trisaccharides		
melezitose	+	0.064*
raffinose	+	0.20*
Polysaccharides		
levo-glucosan	−	−
xylan	−	−
glycogen	−	−
hydroxycellulose	−	−
Polyhydric alcohols		
sorbitol	−	−
glycerol	−	−
dulcitol	−	−
m-erythritol	−	−
penta-erythritol	−	−
mannitol	−	−
L-arabitol	−	−
inositol	+	0.194*
Glycosides		
α-D-methyl glucoside	+	0.069*
β-D-methyl glucoside	−	−
NO_2-benzyl glucoside	−	−
p-aminophenyl glucoside	+	
monoacetyl NO_2-β-glucoside	−	−
phenyl β-glucoside tetraacetate	−	−
α-D-methyl mannoside	+	
p-aminophenyl β-maltoside	+	
nitrophenyl maltoside	+	
7-acetyl *p*-nitrophenol cellobioside	−	−
Substituted Sugars		
n-acetyl glucosamine	−	−
glucosamine hydrochloride	+	0.204
NO_2-α-glucose	+	
NO_2-β-glucose	±	
diacetone glucose	+	
α-pentaacetyl glucose	−	−
diacetone nitrobenzoyl glucose	−	−
1,2,3,4-acetyl-6-trimethyl glucose	−	−
β-NO_2-tetraacetyl glucose	−	−
α-D-glucose-1-phosphate (dipotassium)	−	0.101
α-D-fructose-6-phosphate (barium salt)	−	−
glucose-6-phosphate (barium)	−	0.083
α-D-fructose-1,6-diphosphate	−	−
(calcium)	−	−
(barium)	−	−
(magnesium)	−	−
NO_2-maltose	+	
NO_2-7-acetyl maltose	−	−
NO_2-cellobiose	?	?
sucrose octaacetate	−	−
diacetyl glucuron	−	−
β-triacetyl glucuron	−	−
glycuronic acid monobenzoate	−	−
gulonic lactone	−	−
α-glucoheptonic lactone	−	−

other insects have been reported to be sensitive to aliphatic polyhydric alcohols (cf. Weis, 1930; Haslinger, 1935; Schmidt, 1938). Thus, for example, starved *Calliphora* respond to sorbitol, dulcitol, and mannitol.

The size of the molecule as a whole appears to be critical only within certain limits. Thus, at the smaller extreme some pentoses stimulate, while at the other extremes certain trisaccharides stimulate. As a matter of fact, when the tarsi as a whole are considered, there are no significant differences among the acceptance thresholds of the pentose fucose (0.087 *M*), the hexose glucose (0.132 *M*), the disaccharide trehalose (0.133 *M*), and the trisaccharide melezitose (0.064 *M*). However, polysaccharides (stachyose, a tetrasaccharide, has not been tested) are non-stimulating.

Although threshold values have not been obtained for a large number of compounds acting on single hairs, a sufficient number of comparative experiments have been conducted to show that all sugars are not equally stimulating and that the order of effectiveness for single hairs follows without exception the order as indicated by the tarsal threshold values. Thus the values listed in Table 1 can be accepted with fair assurance as illustrative of the comparative stimulating effectiveness of the various compounds on any single hair.

The important characteristic of the effective compound sugars, recognized by von Frisch (1935) and by Hassett et al. (1950), is not the position of the carbon through which the units are linked but rather the possession of an α-D-glucopyranoside link. For example, maltose with a 1,4-linkage, turanose with its 1,3-linkage, and the non-reducing sucrose are stimulating sugars, whereas lactose with its 1,4-linkage and melibiose with its 1,6-linkage both lack the α-link and are non-stimulating. The effect is not all-or-none; but invariably the compounds with the α-link are superior stimuli. The most striking difference is seen in the great effectiveness of α-methylglucoside in contrast to the ineffectiveness of β-methylglucoside. With glucose itself no significant difference in threshold could be detected between freshly prepared solutions (principally α) and older solutions containing a mixture of α and β. But this failure is not surprising in view of the fact that one solution is a mixture, one component of which, α-glucose, is rather stimulating. On the other hand, it was possible to demonstrate a difference between α-nitroglucose and β-nitroglucose, the former being somewhat more effective. Differences between α and β forms are equivalent to *cis* and *trans* position differences; consequently, it is not altogether surprising to find as great a difference between an α and β form as between α-D-galactose and α-D-glucose, which differ only in the relative positions of H and OH on number 4 carbon.

In one instance, at least, a difference could be detected between D and L stereoisomers. D-arabinose is markedly more stimulating than L-arabinose. On the other hand, no difference between D- and L-xylose could be demonstrated. It should be noted, however, that xylose is not especially stimulating in any case.

When one attempts to analyze the stimulating effectiveness of the monosaccharides in terms of their configuration, it is still not possible to extend the conclusions of von Frisch (1935), who stated at that time that the biological activity of the sugars just does not find expression in their structural formulae. Clearly some configurations are more effective than others. Small differences, as between ribose and arabinose or galactose and glucose, are reflected as great physiological differences. Yet larger differences frequently have little effect. Certain amounts of substitution within the molecule (Table 1) can be tolerated. Strangely enough, even groups as large as phenyl radicals may be substituted without rendering the molecule completely ineffective. Acetyl substitution is invariably detrimental, but this could well be the result of some repellent effect, because acetyl groups are fairly easily hydrolyzed. Gross differences in ring structure may have less influence than certain smaller differences within the ring. One need but recall that inositol is nearly as stimulating as glucose. Furthermore, there is no evidence to support an idea that any one of the cyclic forms of a sugar, viz., pyranose or furanose, is more effective than the other. It is not possible to test this point thoroughly, because, even though all free sugars exist as pyranoses, an equilibrium exists in solution between the various cyclic and the acyclic forms. The pyranose form usually is present in the greatest concentration. However, some of the substituted sugars exist as furanoses. One of these which was tested and found to be stimulating is diacetone glucofuranose.

Although one can come no nearer to relating structure to activity than is possible in enzyme or antigen-antibody studies, where infinitely more facts are available, the conclusion seems clear that

the reaction between the sugar molecule and the receptive surface must be of a comparable nature. Every fact argues against the reaction being either of a general physical nature (e.g., an osmotic effect, etc.) or a simple chemical reaction. The existence of some highly selective receptor substance is strongly indicated.

An obvious exploratory step is that of seeking changes in sensitivity in the presence of different temperatures, hydrogen ion concentrations, enzyme inhibitors, possible competitive inhibitors, and hexose phosphates. Such tests have yielded negative results. Because of the sensitivity of the legs and labellum to temperature changes, no differences in threshold which could be attributed to direct effects were obtained. Similarly, since hydrogen and hydroxyl ions are effective stimuli in their own right (cf. Chadwick and Dethier, 1947) for other responses (see p. 360), no threshold differences above *p*H 8 or below *p*H 5 could have been significant. The usual inhibitors, phlorizin, azide, cyanide, fluoride, iodoacetate, were without effect except in concentrations in which they acted like common inorganic chlorides (see below) in causing rejection. Acetylcholine was without effect. By comparison, certain heavy metal salts, notably $HgCl_2$ and $CuCl_2$, in concentrations ranging from 0.002 to 0.006 *M* rendered the receptors insensitive for periods up to sixty minutes. This fact is in agreement with Deonier's (1938) data which showed that the tarsal receptors of the housefly were rendered insensitive to sucrose for periods up to five hours if exposed to low concentrations of $HgCl_2$.

It has been impossible for the most part to demonstrate any competitive inhibition between sugars. Even if it occurred with glucose and fructose, for example, the fact that each is highly stimulating would obscure the effect. Mannose, which has no repellent effect on the fly and is either poorly stimulating or completely ineffective, causes the threshold for fructose to be elevated by a factor of ten. This effect is produced by mixing the two sugars or by treating the receptors first with 0.5 *M* mannose and then with fructose. Yet the addition of mannose does not alter thresholds for glucose, fucose, sucrose, or maltose.

Finally, the stimulating effect of sugar phosphates was investigated. The thresholds for glucose-1-phosphate and fructose-6-phosphate were not significantly different from that of glucose. Nor were they much different from what might have been expected for any substituted sugar. However, when applied to single hairs, they required higher concentrations for stimulation than did glucose. There seemed also to be a delay in response which is not characteristic of glucose. The Mg, Ca, and Ba salts of fructose-1,6-diphosphate were completely ineffective. One might argue that in the latter instance the salts did not penetrate. If so, these are three of the exceptionally few substances which do not get to the receptor. Altogether, these results weaken any hypothesis that stimulation by sugars involves phosphorylytic reactions. One is still left with the strong suspicion that stimulation does involve some intimate reaction of sugar molecules with a highly selective substrate.

Threshold and summation

Not only is the sugar receptor highly specific, it is also exceedingly sensitive. A fly which is free to use all of its receptors can readily distinguish between water and sucrose solutions as dilute as 1×10^{-7} *M* (Dethier and Rhoades, 1954). Sensitivity to sucrose within the range 1×10^{-7} to 1×10^{-6} *M* is characteristic of many species (cf., e.g. Anderson, 1932; Haslinger, 1935; Minnich, 1929). The individual receptors surely must be sensitive to these dilutions; however, no single receptor ever mediates a response unless the sucrose concentration equals or exceeds 0.00001 *M*. In this respect some receptors appear to be less sensitive than others. A B-type hair on the tibia required 3 *M* sucrose, whereas a C-type required 1 *M*. Most of the B- and C-type hairs of the tarsus required 1 *M* sucrose. Single marginal hairs of the labellum frequently reacted to 0.0001 *M* and in one instance to 0.00001 *M* sucrose.

Absolute threshold values for single hairs, based on behavioral criteria, are without meaning, however, because they actually represent a central nervous system threshold or central excitatory state. Under certain conditions, presumably when the central excitatory state is high, proboscis extensions occur spontaneously, that is, in the absence of any obvious external stimulation. This phenomenon was not formerly observed (Dethier, 1952a), but it is now known to be quite usual, especially in fixed flies which have their feet removed from contact with any surface for long periods of time. Increase in the central excitatory state with a consequent lowering of behavioral threshold may also be brought about by stimulating briefly a

single hair. It has been observed repeatedly that a fly which has failed to respond to 0.1 *M* sucrose applied to the tarsal hairs immediately responds to this concentration if a labellar hair is momentarily stimulated with 0.1 *M* sucrose or a tarsal hair with 3.0 *M*. Another example of the importance of the central excitatory state is to be found in the observation that hairs which mediated responses to 0.1 *M* sucrose when the fly was hungry were apparently insensitive to any concentration of sugar after the fly had been fed 1 *M* sucrose to repletion. Then again, hairs which mediate a response to 1 *M* sucrose will not subsequently respond to any lower concentration even when the fly has not been fed and care has been taken to prevent adaptation. Furthermore, repeated tests show that the relative thresholds of members of a group of hairs change from one time to the next. The most sensitive hair today is not necessarily the most sensitive hair tomorrow. Of course, this change could be a reflection of some change within the receptor itself, but, in view of the other results just mentioned, it is equally likely that it represents some change in the condition of the central nervous system.

Studies of summation provide additional proofs of the importance of the central nervous system threshold. Spatial summation may be demonstrated either on the tibia, where ten of the 31 hairs are conveniently spaced, or on the labellum. Average values from 20 experiments, each with the tibial hairs and hairs of the first tarsomere, show that proboscis extension can be elicited by applying 3 *M* to 1 hair, 1 *M* to a minimum of 4 hairs, 0.5 *M* to 6 to 8 hairs, and 0.1 *M* to a minimum of 10 hairs. The intra-leg spatial summation postulated by Dethier (1953a) is thus convincingly demonstrated. As he further pointed out, it is clear that a response can be elicited either by increasing the concentration of stimulus or by increasing the number of available receptors. The receptors need not necessarily be located on the same leg. Dry sucrose, for example, is strikingly more stimulating when applied to two legs, than when applied to one (for full discussion see Dethier, 1953a). Finally, the *intensity* of response is sometimes manifested as related to the number of hairs stimulated. It has frequently been observed that stimulation of a single hair may elicit vibration or partial extension of the proboscis, whereas stimulation of the two hairs elicits full extension. Furthermore, stimulation of one hair with 0.1 sucrose may elicit only partial extension, while higher concentrations on the same hair call forth full extension.

An indication of the extraordinarily small volumes of solution required is shown by the ability of the fly to respond to crystalline sugars. Tiensuu (1952) first reported that a wide variety of flower-visiting insects could be stimulated by dry sugar or minute amounts of dried nectar. Experiments with *P. regina* and *M. domestica* confirmed his observation. Under certain circumstances it is possible to elicit a proboscis extension by stimulating a single hair with a minute crystal of sucrose. All of the effective compounds listed in Table 1 are stimulating in the crystalline state. The particulate shape of the compound is not a factor influencing stimulation, because there was no correlation whatsoever between effectiveness and crystalline form. All types of crystals were represented, e.g., granules, needles, leaves, plates, powders, etc.

Since intermolecular crystalline forces are such that none of the molecules could affect the receptor unless in a vapor or liquid state, it is reasonable to conclude that a liquid phase must exist at the crystal face or on the receptor surface. The first alternative seemed possible, because sugars are notoriously hygroscopic. To test the possibility, a large crystal of sucrose was kept in a desiccator for one month, then, still in the desiccator, split along a cleavage plane, and one half immediately applied to a group of tarsal receptors. The other half was then applied to labellar receptors. Response to these molecularly clean and dry surfaces was immediate. Secondly, a careful microscopic examination revealed no visible secretion or other liquid on the tip of the hair, as postulated by Tiensuu. However, it is generally believed that all surfaces in nature are covered with at least a mono-layer of water. It is reasonable to suppose that this is the case here and that the first step in stimulation by crystalline sugar is a dissolution of part of the crystal. This being the case, the speed of response is indeed impressive. The fly may respond in a fraction of a second ($\pm$ 0.1 sec.), just as quickly as to a solution.

Adaptation

During the process of stimulation by sugar, as signalled by proboscis extension, adaptation may set in at either of two sites, at the receptor (peripheral) or somewhere within the central nervous

TABLE 2

Rejection thresholds for various compounds mixed with different concentrations of sucrose (S) and applied to the tarsi of Phormia regina

Compound and Molar Sucrose Concentration	Median Rejection Threshold	Log Median Rejection Threshold ± 2.575 S.E.	$a \pm$ S.E.†	$b \pm$ S.E.†	$\bar{x}$†	No. of Tests
NaCl in water	0.044	−1.359 ± 0.245	5.533 ± 0.151	1.978 ± 0.402	−1.087	200
+ 0.01 S	0.127	−0.895 ± 0.142	5.305 ± 0.164	3.090 ± 0.562	−0.797	200
0.1 S	0.387	−0.412 ± 0.219	5.371 ± 0.246	3.168 ± 0.898	−0.295	200
0.25 S	0.491	−0.309 ± 0.152	5.226 ± 0.155	2.676 ± 0.453	−0.225	200
0.5 S	0.589	−0.230 ± 0.144	5.156 ± 0.154	2.770 ± 0.441	−0.174	200
1.0 S	0.970	−0.013 ± 0.234	4.526 ± 0.130	1.765 ± 0.340	−0.283	200
KCl						
+0.01 S	0.159	−0.798 ± 0.175	4.909 ± 0.138	2.015 ± 0.268	−0.843	100
0.1 S	0.249	−0.604 ± 0.232	5.023 ± 0.137	1.519 ± 0.339	−0.589	100
0.25 S	0.516	−0.287 ± 0.319	4.673 ± 0.136	1.287 ± 0.330	−0.542	100
1.0 S	0.951					100
Na propionate in water	0.560	−0.252 ± 0.219	4.484 ± 0.158	2.303 ± 0.514	−0.476	100
+0.01 S	1.10	0.042 ± 0.129	4.939 ± 0.150	3.007 ± 0.424	−0.0211	100
0.1 S	0.368	by graphic interpolation				100
0.5 S	0.766	−0.116 ± 0.139	4.970 ± 0.174	3.830 ± 0.574	−0.124	100
0.9 S	1.300	0.113 ± 0.165	5.051 ± 0.144	3.412 ± 0.476	−0.128	100
Propionic acid						
+0.01 S	0.028	−1.550 ± 0.162	4.993 ± 0.140	2.239 ± 0.359	−1.553	100
0.1 S	0.084	by graphic interpolation				100
1.0 S	0.427	−0.370 ± 0.245	4.924 ± 0.143	2.438 ± 0.376	−0.401	100
Li heptylate						
+0.01 S	0.044	−1.359 ± 0.162	5.228 ± 0.148	2.377 ± 0.383	−1.263	100
0.1 S	0.227	by graphic interpolation				100
0.25 S	0.244	−0.612 ± 0.191	4.679 ± 0.152	2.189 ± 0.416	−0.760	100
Ba acetate						
+0.1 S	0.348	by graphic interpolation				100
0.5 S	0.299	−0.525 ± 0.113	5.026 ± 0.195	4.072 ± 0.647	−0.519	100
Ba caproate						
+0.1 S	0.027	by graphic interpolation				100
1.0 S	0.040	−1.395 ± 0.154	5.025 ± 0.261	2.463 ± 0.702	−1.385	100
Ethanol in water	2.014	0.304 ± 0.113	4.979 ± 0.154	2.820 ± 0.482	0.297	200
+0.01 S	1.297	0.113 ± 0.247	4.893 ± 0.130	1.888 ± 0.281	0.0564	100
0.1 S	2.38	0.377 ± 0.152	5.179 ± 0.248	4.304 ± 1.254	0.418	120
0.5 S	2.228	0.357 ± 0.189	5.014 ± 0.154	3.320 ± 0.465	0.361	100
1.0 S	4.188	0.622 ± 0.113	4.956 ± 0.192	4.413 ± 0.264	0.612	100
Propanol in water	1.05	0.020 ± 0.162	4.734 ± 0.068	1.160 ± 0.121	−0.209	420
+0.01 S	0.878	−0.0565 ± 0.142	4.956 ± 0.140	2.531 ± 0.332	−0.0739	100
0.05 S	0.634	−0.198 ± 0.110	4.992 ± 0.186	4.390 ± 0.722	−0.200	100
0.1 S	1.19	0.077 ± 0.048	5.064 ± 0.170	9.076 ± 1.799	0.084	88
0.25 S	0.888	−0.052 ± 0.159	5.101 ± 0.143	2.334 ± 0.374	−0.008	100
0.5 S	1.02	0.010 ± 0.152	5.246 ± 0.155	2.671 ± 0.444	0.101	100
1.0 S	1.28	0.107 ± 0.133	4.931 ± 0.141	2.667 ± 0.373	0.081	100

TABLE 2—*Continued*

Compound and Molar Sucrose Concentration	Median Rejection Threshold	Log Median Rejection Threshold ± 2.575 S.E.	$a \pm$ S.E.†	$b \pm$ S.E.†	$\bar{x}$†	No. of Tests
2-Butanone						
+0.01 S	0.141	−0.850 ± 0.152	5.169 ± 0.152	2.177 ± 0.430	−0.772	100
0.1 S	0.253	−0.597 ± 0.136	5.136 ± 0.133	2.540 ± 0.297	−0.544	120
0.25 S	0.175	−0.757 ± 0.142	5.343 ± 0.182	3.552 ± 0.378	−0.661	100
3-Pentanone						
+0.01 S	0.018	−1.756 ± 0.126	5.258 ± 0.152	2.515 ± 0.429	−1.653	100
0.1 S	0.053	−1.274 ± 0.145	5.183 ± 0.125	2.258 ± 0.310	−1.194	158
0.25 S	0.054	−1.267 ± 0.130	5.285 ± 0.161	2.554 ± 0.446	−1.155	100
2-Heptanone						
+0.01 S	0.003	−2.571 ± 0.438	5.181 ± 0.187	1.254 ± 0.766	−2.427	100
0.1 S	0.003	−2.529 ± 0.208	4.870 ± 0.208	2.600 ± 0.552	−2.579	105
0.25 S	0.009	−2.068 ± 0.195	4.788 ± 0.141	2.129 ± 0.366	−2.168	100
Ethanediol in water	5.43	0.735 ± 0.139	4.833 ± 0.116	2.175 ± 0.280	0.658	180
+0.01 S	8.41	0.925 ± 0.371	4.647 ± 0.105	1.038 ± 0.318	0.585	100
0.1 S	11.90	1.076 ± 0.046	4.981 ± 0.087	4.858 ± 0.590	1.072	254
0.25 S	28.70	1.458 ± 0.677	4.086 ± 0.197	1.823 ± 0.870	0.957	100
Dipropylene glycol						
+0.01 S	0.226	−0.645 ± 0.227	5.331 ± 0.269	1.997 ± 0.792	−0.479	100
0.1 S	0.794	−0.100 ± 0.148	5.172 ± 0.137	2.648 ± 0.321	−0.035	150
0.25 S	0.607	−0.217 ± 0.193	5.127 ± 0.130	1.769 ± 0.339	−0.145	100
1.0 S	0.978	−0.010 ± 0.187	4.911 ± 0.145	2.002 ± 0.388	−0.055	100
Polypropylene glycol						
400 + 0.01 S	0.0219	−1.659 ± 0.376	5.029 ± 0.143	0.983 ± 0.431	−1.629	100
0.1 S	0.058	−1.235 ± 0.493	5.095 ± 0.532	2.797 ± 1.704	−1.201	100
0.25 S	0.366	−0.437 ± 0.183	4.682 ± 0.152	2.363 ± 0.428	−0.571	100
1.0 S	0.822	−0.085 ± 0.136	3.960 ± 0.195	1.758 ± 0.666	−0.677	100
Polypropylene glycol						
750 + 0.01 S	0.002	−2.669 ± 0.221	5.112 ± 0.202	3.000 ± 0.706	−2.632	100
0.1 S	0.003	−2.528 ± 0.193	5.377 ± 0.165	2.443 ± 0.525	−2.374	100
0.5 S	0.008	−2.074 ± 0.216	4.976 ± 0.211	2.500 ± 0.571	−2 084	100

† The fourth, fifth, and sixth columns of the table give the calculated values for a, b, and $\bar{x}$ in equation $Y = a + b(X - \bar{x})$, which is the regression of the per cent flies rejecting, Y, expressed as probits, on log concentration, X. S.E. = standard error.

system (central). The existence of central adaptation and the importance of its role in the feeding behavior of the fly has been demonstrated (Dethier, 1952a). At the time, peripheral adaptation, though admitted, could not be convincingly demonstrated. It can now be shown quite clearly that, in addition to general central adaptation, there is a local adaptation which occurs either peripherally at the receptor or at the receptor synapse in the ganglion. Any single hair can be adapted, sometimes in a matter of thirty seconds, to the point where no further proboscis extension occurs, whereupon stimulation of an immediately adjacent hair elicits a full response. The phenomenon can be very striking in a hungry fly, which, after adaptation of a labellar hair, will fail to imbibe sucrose unless another hair is stimulated. The relation of adaptation to other aspects of feeding will be discussed elsewhere.

Non-carbohydrate stimuli

Since experimentation first began on the sense of taste in insects it has been known that certain compounds mixed either in water or in acceptable sugar solutions cause the mixtures to be rejected as unacceptable. A number of investigators, notably von Frisch (1935), Frings (1946), Frings and O'Neal (1946), and Chadwick and Dethier (1947, 1949), have put this knowledge to use in investigating the mode of action of unacceptable compounds by measuring values for rejection thresholds. It was realized from the start that sugar concentrations had to be held constant if comparative threshold values were to have any validity, but this aspect of the problem was not investigated further.

The use of mixtures was also resorted to in an attempt to resolve the question of taste modalities in insects (von Frisch, 1935; Frings, 1946). Another approach to the modality question was through the study of summation. On the basis of different patterns of summation Dethier (1953a) postulated a minimum of two types of receptors on the tarsi of *P. regina*, those mediating acceptance, and those mediating rejection. Although alternative interpretations of these results are possible, it is clear at any rate that there were two processes working in opposition.

The first step which has been taken along these lines in the present work has consisted of measuring rejection thresholds in mixtures containing different amounts of sucrose. In these preliminary experiments stimulation was accomplished in the usual way by exposing *all tarsi* of fastened flies to the test solutions. Seventeen organic and inorganic compounds mixed with different concentrations of sucrose were employed. In every case the rejection threshold increased as the sugar con-

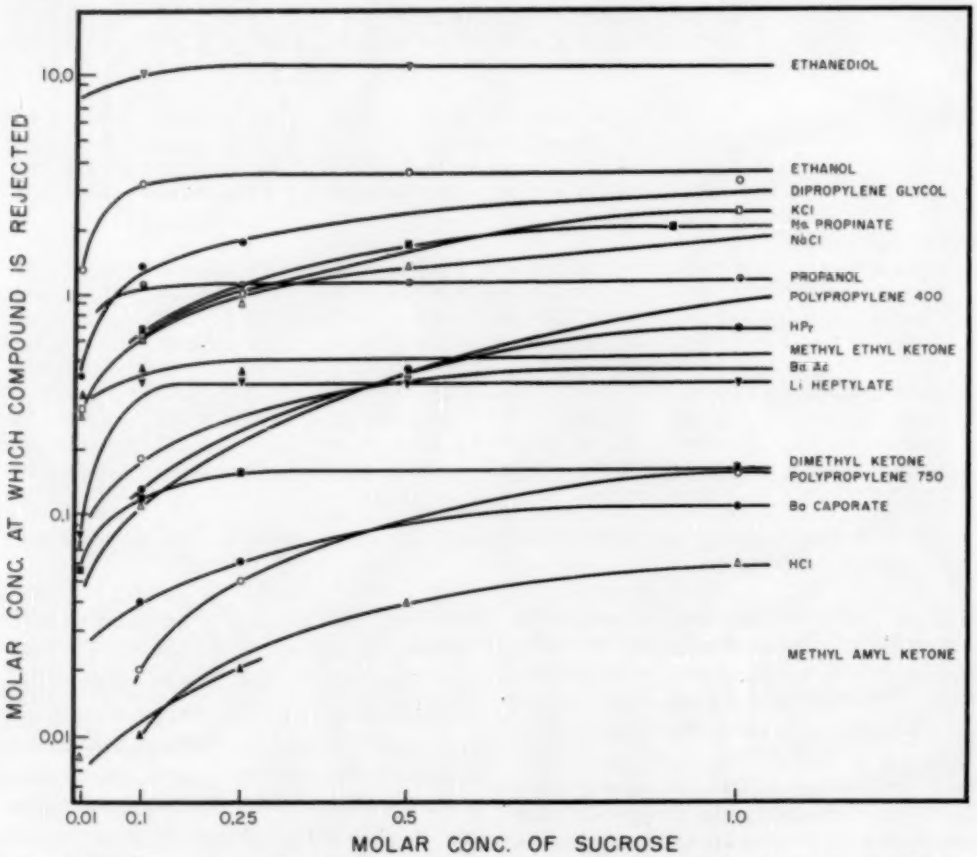


FIG. 3. RELATION BETWEEN THE CONCENTRATION AT WHICH A COMPOUND IS REJECTED AND THE CONCENTRATION OF SUCROSE WITH WHICH IT IS MIXED

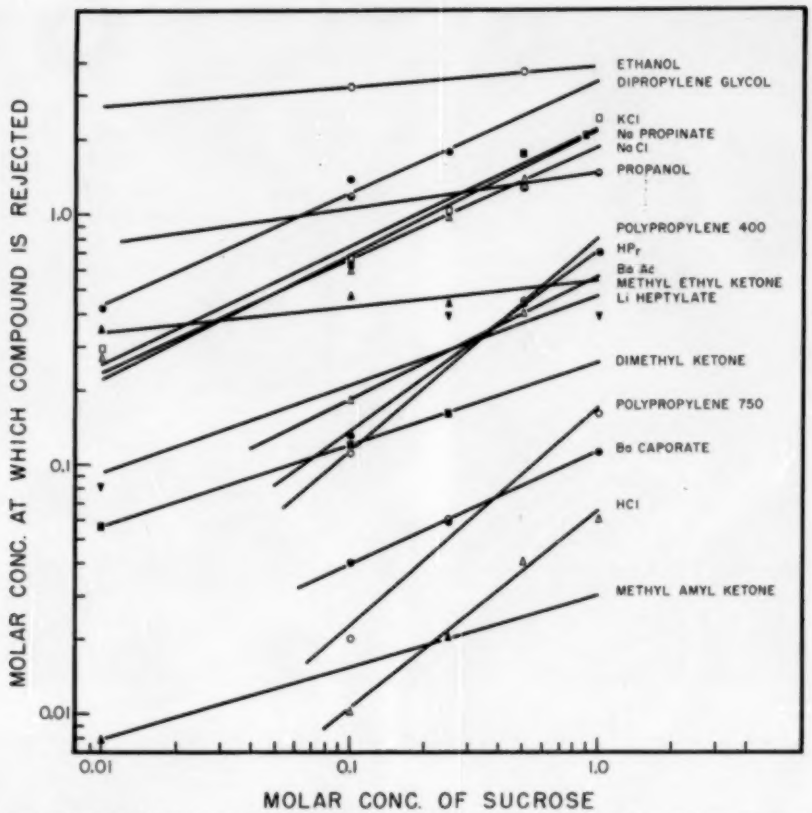
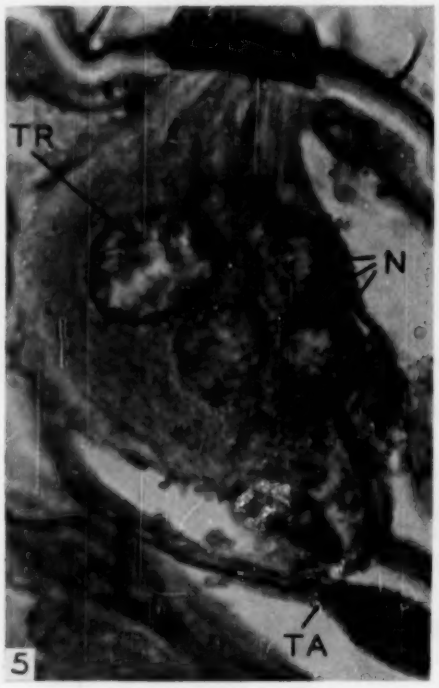


FIG. 4. DATA FROM FIG. 3 PLOTTED LOGARITHMICALLY TO DEMONSTRATE TWO CATEGORIES OF UNACCEPTABLE COMPOUNDS, THOSE WHOSE REJECTION THRESHOLDS CHANGE VERY SLIGHTLY WITH CHANGE IN SUCROSE CONCENTRATION, AND THOSE WHICH CHANGE GREATLY

centration increased (Table 2). Or, conversely, the acceptance threshold of sucrose increased as the concentration of the unacceptable compound increased. The compounds tested fell generally into two categories (Figs. 3 and 4). The inorganic compounds and certain organic compounds (e.g., glycols, fatty acids, fatty acid salts) showed marked increases in the rejection threshold as sucrose was increased. Those organic compounds which in other respects are ordinarily thought of as having a narcotic effect (e.g., alcohols and ketones) showed only slight increases as sucrose was increased. The interdependence of thresholds is in harmony with a concept of two opposing sets of receptors working in balance and supplying input to the central nervous system for integration. The net result, rejection or acceptance, would then depend on the nature of the central integration.

The results obtained in the preliminary experiments just described can be duplicated, however, with individual hairs on either the labellum, tibia, or tarsus. Consider, for example, some typical data obtained from stimulating one of the larger labellar hairs. When a fly is in a hypersensitive state as a result of repeated stimulation of any sort, or has been without food and water for 24 hours, slight bending of a hair at its tip will elicit an extension of the proboscis. Under all other conditions of nutrition and central excitation this fails. When tactile stimulation is continued, adaptation rapidly develops to a point where no response is given. If now a drop of water is placed upon the hair, extension is immediate. In due course adaptation to water sets in; and there is no further response even though the fly has not been permitted to drink. The next step consists of stimulating the hair with 0.001 *M* sucrose. Once again the proboscis is extended. As already described, the hair can now be adapted to various concentrations of sucrose in turn. If, however, the hair is



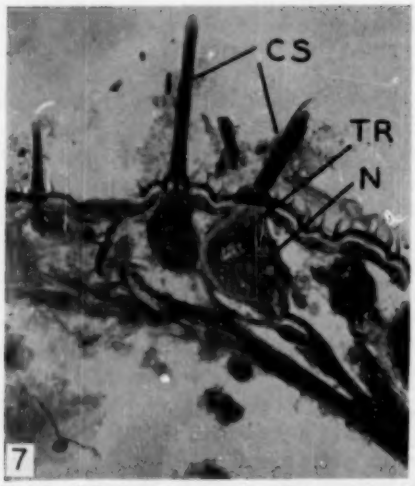
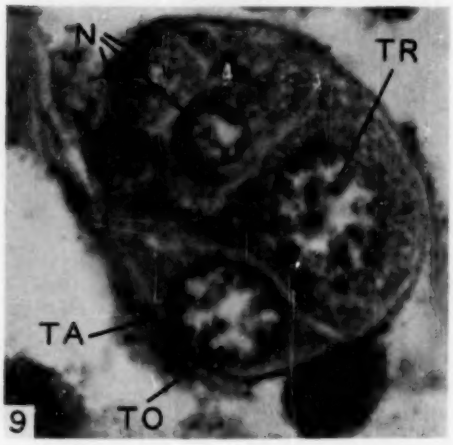


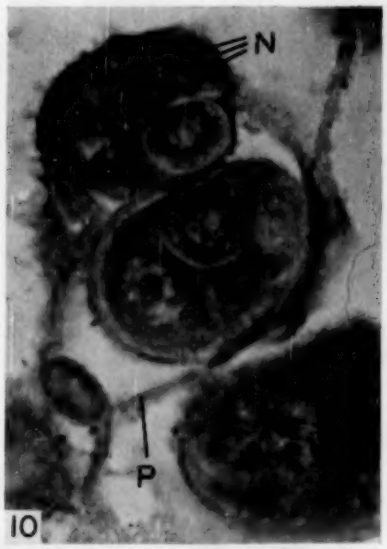
FIG. 5. Cells Associated with a Chemosensory Labellar Hair (× 1700)

FIG. 6. Longitudinal Section through the Labellum of *PHORMIA REGINA* Showing Chemosensory Hairs on Aboral Surface and Interpseudotracheal Papilla on Oral Surface (× 150)

FIG. 7. Innervation of Chemosensory Hairs on Aboral Surface on Labellum (× 330)

FIG. 8. Section through Base of Labellar Hair showing Two Lumina, Distal Fibers of Two Neurons, and the Vacuole of the Trichogen (× 1700)





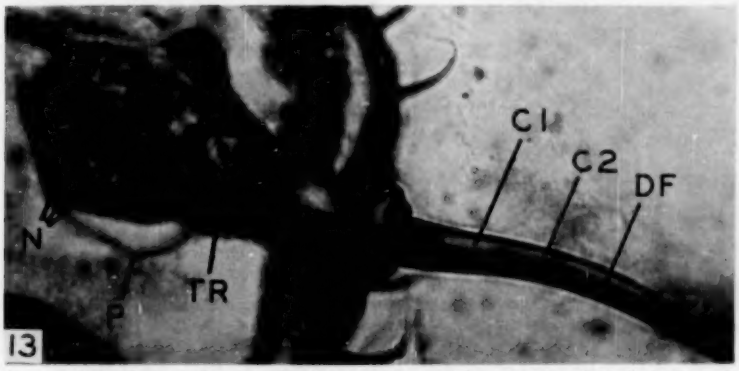
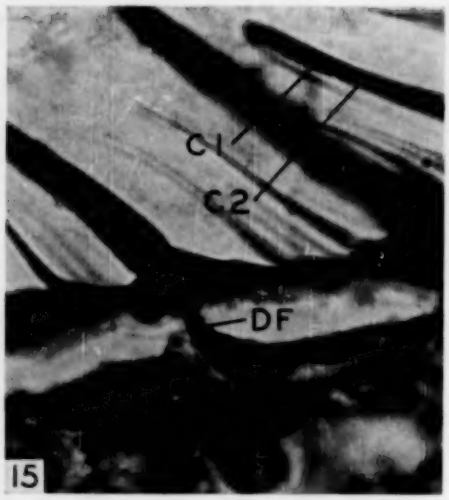
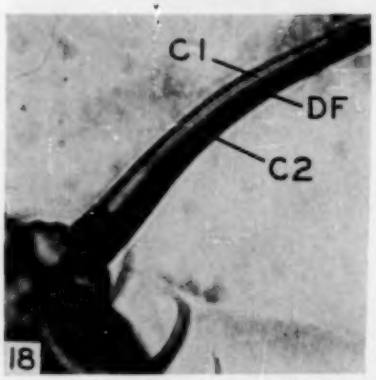


FIG. 9. A Cross Section through Sac of Cells Associated with Chemosensory Labellar Hair (× 1700)
FIG. 10. Same at Lower Level showing Network of Pigment Cells (× 1700)
FIG. 11. Section through Base of Labellar Hair Showing the Two Distal Fibers Entering the Thick-Walled Cavity (× 1700)
FIG. 12. Three Neurons at the Base of a Labellar Hair (× 1700)
FIG. 13. Medium-Sized Labellar Hair with its Neurons and Associated Cells. Note distal fiber in thick-walled cavity (× 1700)





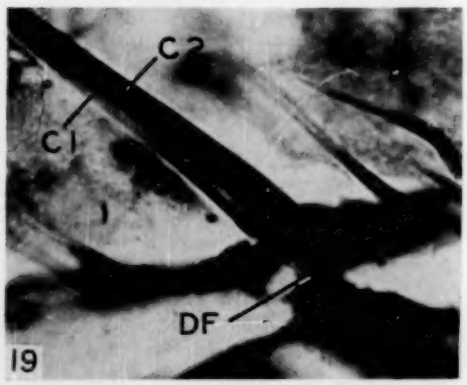


FIG. 14. Section through Cells at the Bases of a Chemosensory and a Tactile Hair of Tarsus Note the large single bipolar cell which innervates the tactile hair (× 1700)

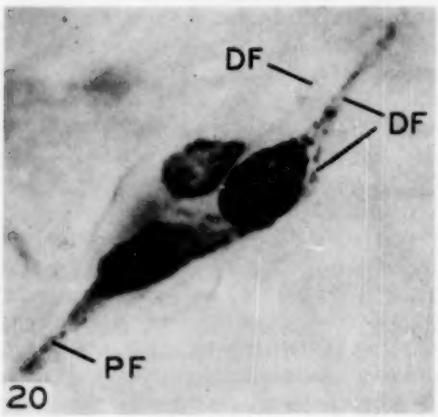
FIG. 15. Distal Fibers Entering one Lumen of a Tarsal Chemosensory Hair (× 1700)

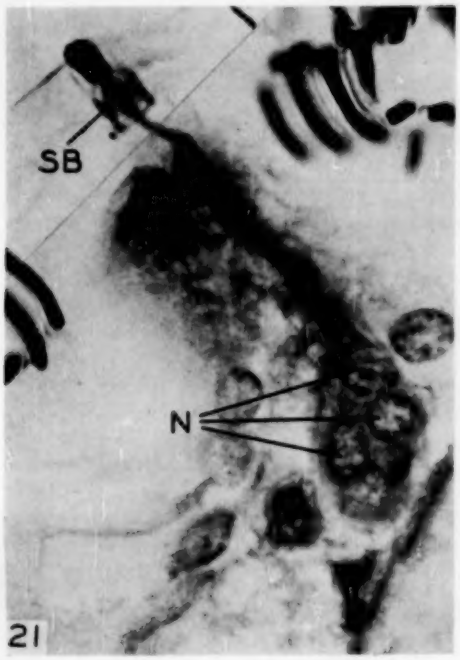
FIG. 16. Two Distal Fibers Entering Base of Labellar Hair

FIG. 17. Terminal Papilla on Labellar Hair (× 1700)

FIG. 18. Section through Labellar Hair Showing Two Lumina and Distal Fiber in Thick-Walled Area (× 1700)

FIG. 19. Section through Tarsal Hair Showing Distal Fibers Entering Thick-Walled Area





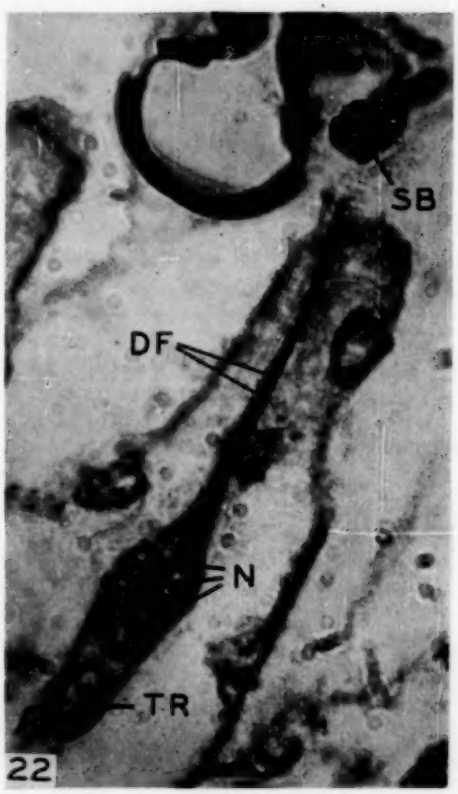


FIG. 20. Methylene Blue Whole Mount Preparation of Base of Labellar Hair (× 1700)
FIG. 21. Interpseudotracheal Papilla and its Associated Cells (× 1700)
FIG. 22. Interpseudotracheal Papilla and its Associated Cells
FIG. 23. Interpseudotracheal Papilla and its Associated Cells

TABLE 3

Responses obtained by stimulating a single hair with various chemical mixtures

Series	Solution Components and Molar Concentrations	Character of Response (+ = extension; − = inhibition)
I	0.01 sucrose	+
	0.01 sucrose + 0.1 NaCl	+
	0.01 sucrose + 0.5 NaCl	−
	0.1 sucrose + 0.5 NaCl	+
	0.1 sucrose + 1.0 NaCl	+
	0.1 sucrose + 2.0 NaCl	−
	0.1 sucrose	+
II	0.01 sucrose	+
	0.01 sucrose + 0.5 NaCl	−
	0.01 sucrose	+
	0.01 sucrose + 0.5 NaCl	−
	0.1 sucrose + 0.5 NaCl	+
	0.1 sucrose + 2.0 NaCl	−
	0.1 sucrose	+
III	0.1 sucrose	+
	0.1 sucrose + 1.0 propanol	−
	0.1 sucrose	+
	0.1 sucrose + 1.0 propanol	−
	1.0 sucrose + 1.0 propanol	+
IV	0.01 sucrose	+
	0.01 sucrose + 1.0 propanol	−
	0.1 sucrose + 1.0 propanol	+
	1.0 sucrose + 1.0 propanol	+
	1.0 sucrose + 4.0 propanol	−
	1.0 sucrose	+
V	0.01 sucrose	+
	0.01 sucrose + 1.0 propanol	−
	0.01 sucrose	−
	0.1 sucrose + 1.0 propanol	+
	0.1 sucrose + 2.0 propanol	−
	0.1 sucrose	−
	1.0 sucrose + 2.0 propanol	−
	1.0 sucrose	−

stimulated instead with a mixture of sucrose and NaCl or sucrose and propanol, the proboscis is retracted or extension is inhibited. Subsequent application of sucrose alone evokes a response, thus indicating that previous failure was not a result of adaptation. The hair can be stimulated in the sequences listed in Table 3 with the results shown.

It is clear that: (1) the rejection threshold value for both organic and inorganic compounds depends upon the amount of sucrose present in the mixture; (2) the two opposing actions may be mediated by a single hair. With regard to a typical salt, NaCl, Series I in Table 3 illustrates these two points. For the particular experiment described the inclusion of 0.5 *M* NaCl rendered unacceptable an otherwise acceptable solution of 0.01 *M* sucrose. Yet the inhibitory effect of 0.5 *M* NaCl was overcome by increasing the sucrose concentration to 0.1 *M*. In the presence of this concentration of sucrose 2 *M* NaCl was now required to cause rejection. Series II illustrates the same point with the additional information that sucrose alone, presented after a rejected mixture, brought about immediate response, thus proving that previous rejection had not been a result of adaptation to sucrose.

In Series III and IV where a typical alcohol, propanol, was mixed with sucrose, the events just described for NaCl were repeated. At the 0.1 *M* sucrose level in Series III and the 0.1 *M* level in Series IV there is again an indication that adaptation to sucrose was not the cause of failure to respond. In Series V at the 0.01 *M* sucrose level and at the 0.1 *M* level there was failure of response. It was overcome only by increasing the sugar concentration.

The action of NaCl and of propanol differs in two respects. First, there is the failure just mentioned. It has not been known to occur with NaCl. Second, NaCl concentration must be increased by a factor of eight to prevent responses to sucrose over the range 0.01 *M* to 1.0 *M*, whereas propanol need only be increased two- to four-fold to inhibit over the same range. This result agrees very well with the data obtained earlier by stimulation of all legs, as shown in Table 2, where the factor of increase for NaCl is 7.6 and for propanol approximately 1.5. Another point which must be emphasized is that the inhibition described above is almost immediately reversed either by removal of the inhibiting compound or by the addition of a greater concentration of sucrose. By contrast, the inhibition produced by heavy metal salts or by high concentrations of narcotics is of longer duration and is not readily reversed by increasing sucrose concentration (cf. also Deonier, 1938).

Two equally plausible hypotheses may be advanced to explain the foregoing results. Either the unacceptable compounds act as reversible inhibitors on the sugar receptor, the degree of inhibition depending not alone on the concentra-

tion of inhibitor but also upon the concentration of sucrose; or else sugar acts through the medium of one neuron and unacceptable compounds through the other; in other words, there may be an inhibitory fiber.

At this point it may be well to raise the question of the distinction between sensillum and receptor. Heretofore it has been customary to think of a seta (modified or otherwise) and its associated cells as a sensillum specialized for the reception of one type of stimulus. Thus a sensillum was *either* tactile *or* gustatory *or* olfactory, etc. From time to time there were cautious statements in the literature to the effect that a sensillum might be tactile and gustatory. A multi-innervated sensillum might quite plausibly subserve more than a single function. The hairs described here quite obviously do. The characteristic double-walled hairs of the labellum, tibia, and tarsus are alike in that they can mediate response to touch and to chemicals. However, tactile stimulation of the hairs of the tibia and tarsus elicits withdrawal of the leg, while tactile stimulation of the labellar hairs elicits extension of the proboscis. The fact that the sensillum can become adapted to one type of stimulus while remaining sensitive to another is a strong indication that one stimulus acts upon one neuron and the other on one of the remaining neurons. It is also significant that a hair with its tip removed remains sensitive to tactile stimulation but no longer responds either to water or to sucrose. We must then speak of the neuron and its associated processes as the receptor; the sensillum, at least in this case, is an organ consisting of several receptors.

In so far as the chemosensory hairs of *Phormia* are concerned, are there, then, two chemoreceptors, one for sugars and another for non-carbohydrates, as Dethier (1953) postulated, or is rejection and acceptance explicable in terms of a dual action of a single receptor? The following experiment was designed to resolve this question. The test is accomplished by stimulating one labellar hair with sucrose and another with NaCl or propanol. When this is done the response is governed by the relative strengths of the two stimuli. If the unacceptable stimulus is strong and the sugar weak, there is no extension of the proboscis. If the sugar is strong and the opposing stimulus weak, proboscis extension occurs. The results show that such compounds as NaCl and propanol may cause rejection without inhibiting the action of sugar at the site of stimulation (cf. also Dethier, 1953). The principal site of interaction between the opposing stimuli is in all probability within the central nervous system where input from the sugar receptor and from the non-sugar receptor is integrated.

In this connection it is interesting to recall the electrophysiological recordings which Andersson, Landgren, Olsson, and Zotterman (1950) obtained from the chorda tympani of the dog when they stimulated the tongue with mixtures of acid and sugar. As far as impulse frequency in the afferent nerve is concerned, a combination of acid and sugar sums algebraically. There was no evidence of peripheral interaction. Depression of acid taste by sugar, as commonly experienced by man, undoubtedly derives, therefore, from the integrating action of the central nervous system.

Adequate stimulus for non-sugar receptors

In sharp contrast to the sugar receptor, the non-sugar receptor is spectacularly non-specific. Evidence available at the moment suggests that any compound which is rejected by a fly whose tarsi or mouthparts are stimulated can act effectively on a single labellar or tarsal hair provided that a critical concentration can be brought to bear. Spot tests with selected anions, cations, and alcohols show that any given hair is sensitive to all. There is no indication that the fly possesses specific salt, acid, or salt-acid receptors comparable to those discovered in the cat by Pfaffmann (1941). The findings with flies are in agreement with Hodgson's (1953) observations that salt-, acid-, and alcohol-sensitive areas of the water beetle *Laccophilus* are identical and not distinctly localized, as Ritter (1936) believed them to be in *Hydrous*.

For the reasons stated earlier, it is difficult to obtain accurate threshold values for single hairs. Nevertheless, it is almost certain that many of the relationships between stimulating effectiveness and chemical properties, as derived from studies of receptor populations, are equally valid for single receptors. Thus, for example, the order of stimulating effectiveness of cations tested on single labellar hairs of *Phormia* is $Li^+ < Na^+ \leqq K^+ < Ca^{++} <<< H_3O^+$. For anions the order is $CH_3COO^- < Cl^- < NO_3^- <<< OH^-$. With the exception of K^+, the order is similar to that obtained by Frings (1948) with a variety of species, namely $Li^+ < Na^+ < Ca^{++} < K^+ \leqq NH_4^+ < < H_3O^+$. Furthermore, our experiments with single hairs

have shown that there is no ionic antagonism between K^+ and Ca^{++}. On the contrary, the effect is additive.

In so far as organic compounds are concerned, only methanol, ethanol, propanol, and butanol have been tested on single hairs thus far. The order of stimulating efficiency is in the order stated above. This result is in agreement with tests on tarsi in which molar thresholds of rejection were found to decrease logarithmically with chain length (Dethier and Chadwick, 1947). Further tests with mixtures on single hairs have revealed that the effects of different alcohols are additive and that the effects of NaCl and propanol are additive.

In view of the uniformity of agreement between the various spot tests in single receptors and the information derived from gross experiments, it is probable that the latter information can be interpreted as reflecting the conditions which characterize a single receptor. If this belief is correct, then it can be concluded that (1) the stimulating efficiencies of cations (heavy metals excepted) are correlated with ionic mobilities (Frings, 1946, 1948); and (2) the stimulating efficiency of aliphatic organic compounds is correlated with solubility (Dethier and Chadwick, 1950). In all probability the limiting mechanism in stimulation of non-sugar receptors involves as a minimum a two-phase system (Chadwick and Dethier, 1949). In other words, smaller molecules gain access to the critical receptor area through an aqueous phase, while the larger aliphatic molecules enter principally through a lipoid phase. For a complete thermodynamic analysis of the limiting mechanism the work of Dethier (1951) should be consulted.

Water as a stimulus

It must be remembered that a thirsty fly responds to water in much the same manner as a water-sated fly responds to sucrose. In this connection it is of interest to recall that Zotterman (1949, 1950) and Andersson and Zotterman (1950) located in the glossopharyngeal nerve of the frog one set of fibers which responded specifically to water and weak NaCl solutions (0.025%) and other fibers which responded specifically to hypertonic NaCl (0.5–2%). A 5.5% solution of sucrose produced a discharge which was indistinguishable from that produced by water (Zotterman, 1949). This result indicates that the water effect was not due to osmosis. Since KCl inhibited the water response and $CaCl_2$ did not, it was assumed that the water effect is due to withdrawal of potassium ions.

In the fly it is conceivable that the sugar receptor and water receptor are one and the same. As stated earlier, only two nerve fibers can be seen ascending to the tip of the hair. The tip is the only area sensitive to chemical stimulation. The hair can be adapted to water and to successive concentrations of sugar in turn. Preliminary experiments indicate that there is no cross adaptation to sugar and unacceptable compounds (cf. Dethier, 1952).

The mode of action of water as a stimulus is unknown. Both K^+ and Ca^{++} stimulate the non-sugar receptor, and there is no evidence from behavioral studies that K^+ specifically inhibits the water or sugar receptor. Proof is lacking to the effect that stimulation by water involves a loss of K^+ from the fiber. If the sugar and water receptor are indeed one and the same, some explanation must be sought for the high specificity to certain sugars which becomes apparent after a fly is no longer thirsty.

STIMULATION OF SENSILLA ON ORAL AND INTERNAL SURFACES

Interpseudotracheal papillae

In the course of experiments with labellar hairs it was observed from time to time that some solutions were regurgitated when placed upon the oral surface of the labellar lobes but out of reach of the aboral hairs. This bit of behavior directed attention to the presence of other innervated structures in the proboscis. The small sensilla basiconica located between the pseudotracheae are admirably situated to monitor solutions about to be imbibed. In order to stimulate the sensilla basiconica without also stimulating the labellar hairs, the latter were put out of commission by a thorough application of paraffin wax. Local waxing is accomplished most easily either by placing melted paraffin on the proboscis of an active fly which by regurgitation keeps the oral surfaces clear, or by waxing the entire closed proboscis of an anaesthetized fly and then slitting open the paraffin between the labellar lobes. Another technique relies upon the successful insertion of micropipettes between the labellar lobes. In any case solutions may be applied solely to the sensilla basiconica.

With the labellar hairs rendered inoperative the fly still seems to be capable of distinguishing between water and sucrose. The normal fly replete with water will freely drink sugar solutions. A treated fly which is allowed to drink water to satiety will refuse water but still accept sucrose. If either water or sucrose is replaced with or has added to it NaCl, propanol, or any other ordinarily unacceptable compound, a treated fly will immediately regurgitate. The reaction is strikingly rapid. If the labellum is now rinsed with water and either water or sugar is applied, there is an appreciable delay, a minute or more, before sucking recommences. The delay would suggest that an acceptable solution is not particularly stimulating and that a certain central inhibition must decay before feeding can be resumed.

Pharyngeal and epipharyngeal sensilla

A possibility remains that certain sensory structures on the pharynx and labrum-epipharynx (Künckel and Gazagnaire, 1881; Kraepelin, 1882; Graham-Smith, 1930; and Hertweck, 1931) may also be gustatory. Frings and O'Neal (1946) attempted to check this point by observing the feeding reactions of *Tabanus* from which the labellar lobes had been removed. *Tabanus* failed to respond to sugar even when the proboscis was immersed up to the frons. This result indicates either that the solution did not get into the region of the receptors in question or that the receptors are insensitive to sugar. In additional tests a mixture of sucrose and NH_4Cl (refused by normal flies) was imbibed.

When the tarsi of the mutilated flies were placed in sucrose, the solution was imbibed as might be expected. When the tarsi were placed in the mixture, it was not imbibed. It is not made clear in this last instance, however, whether or not the proboscis was extended. If it was extended and the mixture was refused, this would suggest the presence of receptors within the oral cavity. If, on the other hand, it was not even extended, this was a result of adverse stimulation of the tarsal receptors, and neither proves nor disproves the function of pharyngeal and epipharyngeal receptors. When *Phormia* lacking labella were stimulated on the tarsi with sucrose (to induce sucking) but presented with NaCl, the proffered solution was not imbibed. However, the rapidity of the rejection suggested that the salt was stimulating the wounded area rather than receptors at a deeper location. Even a delayed refusal would not have constituted proof of pharyngeal receptors, because internal stimuli arising as a result of adverse conditions in the gut could lead to rejection of salt solutions. Additional experiments will certainly be necessary before the nature of these receptors is clearly established.

SUMMARY

1. The contact chemoreceptors of the flies *Phormia regina*, *Protophormia terra-novae*, *Musca domestica*, *Calliphora erythrocephala*, *C. vomitoria*, and *Drosophila melanogaster* are located on the legs and labellum. Those on the legs and aboral labellar surface are thin-walled, socketed hairs (sensilla trichodea) with two lumina. Those on the oral labellar surface are small sensilla basiconica known as interpseudotracheal papillae. The hairs are equipped with three neurons, of which two send distal processes to the tip. Only the tip of the hair is sensitive to stimulation by chemicals.

2. Chemoreceptive hairs may be stimulated by bending, by water, or by sugars, but any hair may be adapted in turn to each type of stimulus. Stimulation of a single hair is sufficient for a complete behavioral response. A hair is actually a small organ consisting of at least two receptors. The sugar receptor is highly specific. Stimulation of this receptor results in extension of the proboscis and imbibition of liquids. The non-sugar receptor can be stimulated by a very great variety of organic and inorganic compounds. Response to stimulation of this receptor takes the form of proboscis retraction or, if the proboscis is already retracted, inhibition of extension. It is highly probable that of the two neurons which send fibers to the tip of the hair, one is the sugar receptor and the other the non-sugar receptor.

It is possible that the stimulation of thirsty flies by water is effected through the sugar receptor. While it would be satisfying to ascribe a mechanical function to the third neuron, this neuron does not conform to the specifications of known mechano-receptors.

3. The most effective carbohydrate stimuli for the sugar receptor are certain pentoses, hexoses, and compound sugars possessing an α-D-glucopyranoside link. In general the α-form of a sugar is a better stimulus than the β-form. D-Arabinose is more effective than L-arabinose. The structural configuration of the sugar molecule is most important in influencing stimulatory effectiveness.

Enzyme inhibitors such as azide, iodoacetate, phlorizin, and fluoride do not prevent stimulation. Inorganic salts of mercury and copper inhibit reversibly. Mannose causes an increase in fructose threshold but not in those of glucose, sucrose, fucose, or maltose. Hexose monophosphates are nearly as effective as the parent sugars. Diphosphates are ineffective.

4. The lowest threshold value obtained with sucrose for any single hair was 1×10^{-6} *M*. Since acceptance and rejection thresholds are measured by behavioral methods, they actually represent central nervous system thresholds. They can be lowered by exciting the fly with other modes of stimulation. Thresholds vary in time; i.e., the order of sensitivity within a group of hairs changes from one period to another. Spatial summation can be demonstrated. Responses can be elicited either by increasing stimulus concentration or by increasing the number of hairs stimulated. The intensity of response varies with the number of hairs stimulated. Any hair can be completely adapted without its neighbor being measurably affected.

5. The rejection of unacceptable compounds can be mediated through a single hair. Whether or not a mixture of sugar and repellent applied to a hair elicits acceptance or rejection depends upon the relative concentrations of the two components. Rejection threshold values are related to sugar concentration. As a rule the thresholds for electrolytes change greatly with changes in sugar concentration, whereas thresholds for non-electrolytes vary but little.

6. Interpseudotracheal papillae are sensitive to stimulation by unacceptable compounds. A fly can distinguish between water and either electrolytes or non-electrolytes by means of its papillae alone. The papillae also appear to be sensitive to sugars.

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NEW BIOLOGICAL BOOKS

The aim of this department is to give the reader brief indications of the character, the content, and the value of new books in the various fields of Biology. In addition there will occasionally appear one longer critical review of a book of special significance. Authors and publishers of biological books should bear in mind that THE QUARTERLY REVIEW OF BIOLOGY *can notice in this department only such books as come to the office of the editor. The absence of a book, therefore, from the following and subsequent lists only means that we have not received it. All material for notice in this department should be addressed to H. B. Glass, Associate Editor of* THE QUARTERLY REVIEW OF BIOLOGY, *Department of Biology, The Johns Hopkins University, Baltimore 18, Maryland, U. S. A.*

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GENERAL BIOLOGY: PHILOSOPHY AND EDUCATION

THE SCIENTIFIC ADVENTURE. *Essays in the History and Philosophy of Science.*

By Herbert Dingle. Philosophical Library, New York. $6.00. ix + 372 pp. + 1 pl.; text ill. 1953.

Among contemporary philosophers and historians of science, the eminent Professor of these branches of learning in University College, London, stands almost alone. Few indeed combine his breadth of training or his penetration into philosophical matters that all scientists should concern themselves about, and so few do. These collected essays, all but one or two of which have previously been published elsewhere, present much food for thought, pithily expressed. The introductory essay is entitled The Missing Factor in Science, and was Professor Dingle's Inaugural Lecture in June, 1947. A few quotations will indicate his point of view, although very inadequately. Two consequences of the nature of modern science are, first, "that science, though a genuine philosophy and not a new upstart activity, will never prove a universally satisfying philosophy. For all its impregnable basis and the stability of its superstructure, it is always essentially unfinished." Second, "the history of science is inseparable from science itself. . . . Science may ignore its history, but if so, it fails." The further consideration of these theses leads to the conclusion that "a critical effort within science . . . can direct the movement itself, so that blind alleys are avoided and the path of progress illuminated; and, still more important for the world as a whole, it can make science self-conscious and aware of the significance of what it is doing in relation to other human activities. It is no small calamity, therefore, that the world of science, with some honourable exceptions, is so indifferent to the attempt to understand and interpret its own activities. It makes no provision for recognizing and encouraging such an endeavour." This is truly a serious indictment. Perhaps it is not altogether justified, but it should serve to awaken somewhat the consciences of many scientists who have indeed never thought about the matter.

One section of the book is entitled Historical Essays. These 8 essays are concerned with astronomical and physical subjects. Part Two: Philosophical Essays, likewise reflects the astronomical and physical training and special interests of the author, but contains some essays that it may be hoped all scientists, whatever

their fields, will take time to read. The Philosophical Viewpoint of a Scientist boldly grapples with the problem of mind, with the subject-object relationship and its relationship to time, and the ultimate nature of experience. Scientists, through prepossession with the idea of physical objects as the necessary objects of knowledge, and through their lack of criteria for distinguishing between the data of experience and the creations of reason, commonly mistake their *concepts*, such as the electron, space, physical time, or the gene, for inviolable data of experience. Dingle suggests that "the problem of philosophy may be expressed as the rational correlation, by the ever-present subject, 'I,' of the elementary experiences which time has made objective by projecting them as memories into the past. . . . All of the world as we know it that can conceivably be rejected or modified is the contribution of reason." This conclusion obviously places the crude scientific materialist, who is still among us, in the position of a naive exponent of an outworn faith.

This line of thought has been further developed in the essay The Nature of Scientific Philosophy, written some 9 years after the essay just discussed. Using Galileo as the originator and outstanding user of modern scientific methods, Dingle points out Galileo's rejection of the world of everyday, common-sense material objects, and his analysis of experiences into their elementary constituents. "He detached the motions of bodies from the properties associated with them in those bodies and sought for laws of *motion* in itself." The peculiar characteristic of scientific philosophy is that, while "like all philosophy its aim is to organize the whole of experience into a rationally connected system, [yet] unlike all previous philosophies, it does not accept the world of material objects, located and moving in a unique world of space and time, as a necessary starting-point, but goes back to the original experiences that led to the conception of that world for practical ends, and groups them differently." ". . . the experiences themselves are the fundamental data of science." Dingle thereupon deduces that no experience has priority over any other; that no realm of experience is excluded from scientific treatment; and that sensations are not in the least more "scientific" than emotions—we have simply not yet learned how to deal with the latter type of experiences rationally and logically. In fact, the restriction to measurement and the use of the "experimental method," so generally thought to be the essential distinguishing characteristics of science, though important, are not so much necessary to the nature of science as valuable because they provide the simplest starting-point for the rationalizing of the whole of experience.

Many other provocative and stimulating thoughts are expressed by Professor Dingle in this and other essays, regarding which there is not enough space to speak. The two final essays, on Science and Ethics and on Science and Religion, respectively, although not definitive so much as exploratory, will provide any reader with ample substance for thought. What we must now hope to get from the author, within the next few years, is a more fully developed and integrated statement of his philosophy of science, not in the form of disjointed essays written over the years, but a mature sequel to his book *Through Science to Philosophy* written in 1937. When such at length appears, scientists will be confronted with one of the major works of the second half of this century.

BENTLEY GLASS

PUBLIC EDUCATION AND A PRODUCTIVE SOCIETY. *Horace Mann Lecture, 1953.*

By Maurice J. Thomas. University of Pittsburgh Press, Pittsburgh. $1.00. iv + 96 pp. 1953.

The subject of this small volume, the 1953 Horace Mann lecture given, it would seem, at the University of Pittsburgh, is the role of public education in building and maintaining a productive society. It deals with criticism of the public school systems, with quality education and its ideals and objectives, and with support of public schools and officials not only financially but spiritually and morally. It ends with an accolade to the public schools for the contributions they have made to the political and lay leadership of the country. The lecture actually contains little that has not been said a thousand times in the past, or that will not be stated a thousand times again by future educators.

A CURRICULUM FOR SCHOOLS OF MEDICAL TECHNOLOGY. *Third Edition.*

Edited by Israel Davidsohn; associate editor, Kurt Stern. Recommended by The Board of Registry of The American Society of Clinical Pathologists, Muncie. $3.00 (paper). 123 pp. 1953.

This is the 3rd edition of a course of study designed to give uniformity and quality of training to those who constitute the laboratory staff of the clinical pathologist. The course covers the usual techniques of routine examination of patients, and provides clear-cut procedures for the training of students. Its recommendation by the Board of Registry of the American Society of Clinical Pathology invests it with a halo of authority; it is undoubtedly a *requirement* in its field.

FOUNDATIONS OF BIOLOGY. *A Laboratory Handbook.*

By Gairdner B. Moment and Helen V. Crouse. Appleton-Century-Crofts, New York. $2.50 (paper). vi + 282 pp.; ill. 1953.

This laboratory manual is planned for use in either a full-year or a one-semester course in college biology. It

includes 40 exercises, each arranged to cover Importance and Purpose; Materials; Procedures; and Useful References. Work sheets for reports and drawings are in the second half of the manual. The authors have wisely avoided that superabundance of printed drawings which the student is merely asked to label, for they hold, as I do likewise, that such extremely formalized laboratory work is of very little value. It emphasizes mere memory of names and structures, and gives the student little chance to demonstrate growth in the capacity for making accurate observations or for thinking in experimental ways. To provoke questions, to observe accurately and to report faithfully, to learn to arrange an experiment to test a hypothesis—surely this is what we should attempt to get students in the biological laboratory to do. Cookbookery vitiates the spirit of science and is largely responsible for the disrepute of laboratory work in science courses at the present time. The authors of this laboratory manual have done much to make the laboratory work they have planned not only fruitful but to a considerable extent original.

Moment and Crouse start with an exercise, entitled The Place of the Laboratory in Modern Science, which is likely to be as valuable for the teacher as for the student, in emphasizing the point of view expressed above. Other original types of exercises are those of an historical character, e.g., Galvani's Experiments; Respiration—Historical; and others in which classical and modern experimentation are interrelated. Novel exercises are those on The Hardy-Weinberg Law: Human Heredity, Population Genetics, and Evolution; and on Evolution: Comparative Anatomy and Systematic Serology. Suffice it to say that this laboratory guide covers exceedingly well the great biological principles, and avoids the attempt to survey the entirety of the plant and animal kingdoms.

BENTLEY GLASS

BIOLOGY: HISTORY AND BIOGRAPHY

RUDOLF VIRCHOW. *Doctor, Statesman, Anthropologist. By Erwin H. Ackerknecht. The University of Wisconsin Press, Madison.* $5.00. xvi + 304 pp. + 3 pl. 1953.

No figure among 19th century German scientists was more versatile, more productive, or more influential than Rudolf Virchow. Known to biologists chiefly as the founder of "cellular pathology" and the author of the famous dictum "Omnis cellula e cellula" that modernized the Cell Theory of Schleiden and Schwann, the eminent doctor was no less eminent both as statesman and as anthropologist. Virchow's liberal political interests began with the period of the 1848 revolution, when he was a young man of 27 years of age. They continued throughout the long period when Conservatism and Nationalism combined to lead to the dominance of Prussia over Germany, to the leadership of Bismarck, and the war of 1870 with France. With rare devotion to liberal and international ideals, Virchow served as a leader of the German Progressive Party and a member of the lower house in Prussia. Consistently and courageously opposing Bismarck, he eventually saw his party defeated and his enemy's objectives achieved; yet even to the end of his long life he maintained his political activity and fought for his liberal ideals.

In the field of medicine Virchow struggled to overthrow the prevailing teleology and humoralism prevailing when he started his career, and to replace them with a medical reform that acknowledged the social importance of medicine and traced the roots of many diseases to the social evils of the time. Besides this, he emphasized the importance of physiology and chemistry in the understanding of pathology. Founding the *Archives of Pathological Anatomy and Physiology, and Clinical Medicine*, he said: "Pathological Physiology is to be a fortress of which pathological anatomy and the clinic are only the forts." Above all he emphasized the cellular character and localization of pathological conditions. Here his political ideas obviously influenced his biological ones, as he conceived, to quote Ackerknecht, "the body to be a free state of equal individuals, a federation of cells, a democratic cell state. [Cellular Pathology] showed it as a social unit composed of equals, while an undemocratic oligarchy of tissues was assumed in humoral, or solidistic pathology." Undoubtedly Virchow transformed the viewpoint of German medicine, and although in later years the rise of bacteriology and the germ theory led to many defections from his point of view, and even to a feeling of opposition on the part of many bacteriologists, it is easier today to see that Virchow was right enough in pointing to the reactions of the cells to various agents, whether infectious or not, as the basis of pathology. Besides the great work on *Cellular Pathology* (1858), which remains his greatest work, Virchow wrote and edited voluminously in this field. A great 3-volume work on tumors, *Die krankhafte Geschwuelste*, with its emphasis on the local causes and local origins of tumors, remained for many years the authoritative work in its field. In addition to his eminence as the founder of modern pathology, one must also credit Virchow, as Ackerknecht points out, with great contributions to epidemiology, from the early days of his investigation into the great Silesian typhus outbreak of 1848, which was attributable, he thought, to bad social conditions, hunger and poor housing. Later epidemics of cholera and typhus in Berlin and elsewhere, the outbreak of famine in the Spessart in 1852, and the occurrence of endemic cretinism and goiter in certain parts of Bavaria strengthened his conviction that "education, freedom, and prosperity were the only effective preventives against the recurrence of such emergencies." In the late 1860's Virchow planned and fought to secure a

sewerage system for the city of Berlin, planned new types of hospital construction, inaugurated meat inspection, developed school hygiene, and collaborated in the development of legal medicine. Always medical reform was foremost in his efforts.

What has already been related would be enough accomplishment for any two more ordinary men in a lifetime; but Virchow was incredibly productive in his labors. In the 1870's a friendship with Schliemann led to a great interest in archeology and anthropology, although already his interest in pathology had led him to many studies of skulls. He emphasized the importance of the skull base in making comparative studies; he pointed out the mixed dolichocephalic and brachycephalic character of the Germans; he conducted a gigantic survey of German school children's hair, eye, and skin color in order to demonstrate the existence of the same diversity of types in a population; and on the basis of his conclusions he fought the growing "racist" views. He held that "nowhere were the Germans racially uniform and least of all were they predominantly blond. . . . Racial and linguistic, cultural, or national traits do not coincide. . . . Language and culture can pass and have passed continuously from one race to another" (Ackerknecht). According to the author, Virchow wrote no less than 1180 anthropological publications, of which 523 dealt with physical anthropology and 518 were devoted to archeological or prehistoric subjects. If by and large this work seems less important than his medical contributions, Virchow nevertheless did much to assure Germany preeminence in this science. He became literally the organizer of German anthropology, promoting congresses, founding publications, establishing museums. There is no doubt whatever that it was his friendship with Schliemann, and perhaps that alone, that led the excavator of Troy to donate his unique collections to Germany. Expeditions to the Near East, to Egypt, to the Caucasus, the editing of three anthropological journals, and attendance and addresses at numerous national and international congresses kept Virchow busy during his last years; yet while doing all this, he kept up his active interest in medicine and politics. To summarize the incredible variety of his activities, Ackerknecht says: ". . . in 1848 Virchow simultaneously worked on the blood and on cholera, wrote the Upper Silesia Report, edited *Die medizinische Reform*, and was active in politics. In the 1860's he simultaneously engaged in the constitutional conflict, experimented with trichinae, wrote his book on tumors, fought for Berlin sewerage, started his archeological diggings, and did the routine work of a busy professor. In the 1870's he simultaneously did the anthropological school survey, counterattacked Haeckel and Klebs, worked for Troy, and fought the Kulturkampf." Indeed tasks for a giant!

Erwin Ackerknecht, author of this fine study of Virchow, is like the subject of his study a native of Pomerania. Trained in Germany in medicine and anthropology, he found no place for liberal ideas in the Third Reich. A more fitting person to write the biography of Virchow certainly could not be found. Ackerknecht's admiration for a great figure in the development of modern medicine is apparent beneath the plain prose of his account.

BENTLEY GLASS

A TRANSLATION OF LUIGI GALVANI'S "DE VIRIBUS ELECTRICITATIS IN MOTU MUSCULARI COMMENTARIUS" —COMMENTARY ON THE EFFECT OF ELECTRICITY ON MUSCULAR MOTION.

By Robert Montraville Green. Elizabeth Licht, Cambridge. $4.00. xxii + 97 pp.; ill. 1953.

LUIGI GALVANI: COMMENTARY ON THE EFFECTS OF ELECTRICITY ON MUSCULAR MOTION.

Translated into English by Margaret Glover Foley; with notes and a critical introduction by I. Bernard Cohen; together with a facsimile of Galvani's De Viribus Electricitatis in Motu Musculari Commentarius (1791) and a bibliography of The Editions and Translations of Galvani's book prepared by John Farquhar Fulton and Madeline E. Stanton. Burndy Library, Norwalk, Conn. $6.00. 176 pp.; ill. 1953.

Galvani's discoveries about the strange behavior of frog's legs, strips of metal, and electrostatic machines some two centuries ago can justly be described as epoch-making, since they led directly, in the hands of Volta, to the first source of a continuous electric current. They also stimulated interest in nerve-muscle relationships and in the study of animal electricity as produced in the electric organs of fish. Hence it seems rather strange that (except for a short fragment translated from the German version twenty years ago by a physicist, William F. Magie) English-speaking readers have had to wait two hundred years for a translation. Possibly less strange is the coincidence of *two* translations since both are connected in one way or another with Harvard University.

The first translation is by Robert M. Green, Emeritus Professor of Anatomy in the Harvard Medical School. The second is by a classical scholar, Margaret G. Foley. Green's translation is accompanied by an informative historical preface by Galvani's "academic heir," Professor Giulio C. Pupilli of the medical school of the University of Bologna, and by a translation of an extensive introduction on animal electricity which Galvani's nephew Aldini wrote to accompany the work of his illustrious uncle. Included also is a translation of an exchange of letters between Galvani and one Carminati concerning the work of Volta and other matters.

Miss Foley's translation is adorned with a lengthy introduction by I. Bernard Cohen which does for the modern reader approximately what Aldini did for the reader of Galvani's day. It provides a general orientation into the intricacies of the subject. The Foley trans-

lation is also accompanied by a clearly reproduced facsimile of Galvani's *De Viribus Electricitatis in Motu Musculari 1791*, and by a bibliography of editions and translations compiled by J. F. Fulton and Madeline E. Stanton.

In several ways these two volumes supplement each other very neatly, e.g., one gives us the Aldini introduction, the other presents a facsimile of the original work. Both include Galvani's original (and dramatic) figures, but the Foley translation is far more complete and the execution of the figures is far better. Possibly the Waverly Press had inferior material to work with. The translations are both eminently readable. As far as the reviewer's somewhat scanty Latin will permit him to judge, both accurately represent the sense of the verbose and sometimes even florid original. Both volumes will remain a useful ornament to American scholarship.

GAIRDNER B. MOMENT

HISTORICAL ASPECTS OF ORGANIC EVOLUTION.
By Philip G. Fothergill; with a Foreword by J. W. Heslop Harrison. Philosophical Library, New York. $6.00. xiii + 427 pp. 1953.

This book has been unaccountably praised in some quarters. It ostensibly purports to be an unbiased historical account of the development of the theory of organic evolution. There is undoubtedly a very great need for such a work; but this one cannot qualify, being biased both by the author's inclination to Lamarckism, and by his religious views. Of the two, the latter is less obtrusive, the former, which derives from the author's assimilation of the views of his teacher J. W. Heslop Harrison, the more pervasive. Yet even with two such biases a valuable work might have resulted had critical judgment and scholarly care been exercised. As it stands, the work is one more addition to the sea of books about evolution which mislead novices and amateurs, and provide solace to the critics and opponents of evolution.

Having made such stringent criticisms, one must attempt to justify them. About the discussion of the Greek and Arabian philosophers there is little criticism to be made. The interpretation of Aristotle's Scale of Being as not essentially an evolutionary concept seems warranted in the light of Edelstein's study, which has escaped the author's attention. Xenophanes' remarkable interpretation of fossils, the most truly evolutionary conception propounded by any of the Greeks, is unmentioned; and the view that Lucretius "did not foster any evolutionary ideas, for he believed that plants and animals could arise fully formed from the earth by spontaneous generation" is not tenable and involves a non sequitur of some consequence; for it can easily be shown that most early evolutionists *did* believe in spontaneous generation whereas the preformationists opposed such ideas. Otherwise, this chapter is probably the best in the book.

A chapter on the Speculative Period Up to 1790 A.D is full of unsound pronouncements and outright errors. Diderot and Oken are pushed into the 16th and 17th centuries; De Maupertius (sic) is dismissed with a sentence and a quotation from H. F. Osborn, who got his historical facts second-hand, too. Oken is dismissed as no real originator of the Cell Theory, but Lamarck and Dutrochet are not mentioned in this connection. Buffon is said to have started by supporting Linnaeus' views regarding species, whereas the exact opposite is true. The two men started at the poles of opinion and gradually came together. In the discussion of other 18th Century ideas, Fothergill is not careful to distinguish between the idea of the Great Chain of Being and that of evolution, as he did in the case of Aristotle; and he has evidently never heard of A. O. Lovejoy's masterly book on this subject, to say nothing of the superb series of critical papers on the early evolutionists written by Lovejoy in the period from 1904–11. Had he known them, his discussion of Kant's place in evolutionary theory would have been vastly improved.

Space will not permit reference to all the minor errors, but spermatozoa were certainly not discovered by Spallanzani in 1786, and Darwin certainly did not believe that all variations were inherited, as the author claims. You don't have to read more than a dozen pages of the *Origin of Species* to see that Darwin really said: "Any variation which is not inherited is unimportant for us," that is, in connection with the theory of natural selection. But let us get to weightier matters. It is in his consideration of the more modern period that Fothergill's prejudices entirely carry him away. Take, for example, the statement: "In the long run, however, small changes in genes could only account for small evolutionary changes"—a statement completely belied by the facts. Consider the statement that chromosome aberrations "are not considered to produce any really new characteristics," a statement that politely bypasses the possibility of the evolutionary significance of position effects. Take the acceptance of Dobell's criticisms of the Chromosome Theory, based on work with *Aggregata eberthi*, the very organism used by Karl Belar in a most brilliant demonstration of chromosome continuity and individuality, a study which naturally is not mentioned since it punctured Dobell's criticisms to such an extent that no one pays any attention to them any more.

Worse is still to come. Chapter 9 is devoted to Modern Causal Theories of Evolution, among which Neo-Lamarckian Ideas receive first place. Here we find much weight placed upon the experiments of Kammerer, experiments the fraudulence of which has been repeatedly pointed out. McDougall's Lamarckian experiment in the training of rats is described at great length, but the criticisms of them by numerous workers

are dismissed with the remark that "McDougall has been able to give full replies to them." Nothing whatever is said of the careful and extended work of Agar and his coworkers which was continued for 36 generations without producing the slightest confirmation of McDougall's claimed results. Similarly, in instance after instance, Fothergill cites the evidence that favors his own views and ignores or casually dismisses the searching criticism or disproof of much of it. Henry Fairfield Osborn's "aristogenesis" and other orthogenetic views are accepted without so much as a word regarding G. G. Simpson's critical analysis of the problem, particularly in *Tempo and Mode in Evolution*, which, since it dates back to 1944, cannot be considered as too recent for the author to have overlooked it, except deliberately. Other outworn and ill-supported views, such as Lotsy's theory of evolution by hybridization and Willis' "age and area theory" are taken uncritically, and no mention is made of their refutation by Simpson, Rensch, Wright, and other notable students of evolution.

On the other hand, when the author undertakes to discuss Modern Neo-Darwinism: Mutations and Selection, he is clearly either not cognizant of modern views or deliberately misinterprets them so as to make it appear that the divergences of view between such geneticists as Muller, Fisher, Wright, Haldane, Stadler, East, and Dobzhansky leave little fundamental agreement between them. The crux of Fothergill's position seems to be that the facts that most mutations are detrimental and that viable mutations occur with great rarity afford substantial grounds for doubting that gene mutations are the raw material of evolution. Space fails to mention the dozens of examples of error and misinterpretation in this section.

The book concludes with an Epilogue that contains some high-sounding words. Among them is this advice: "The danger . . . is that some scientists stop short at the very point at which their truly philosophic reasonings should begin, with the result that their philosophy is made to fit in with their biological theories, instead of interpreting their theories on the basis of principles founded on practically innate and probably surer mental convictions." This book stands as a monument to the folly of doing what the author evidently holds to be the higher wisdom.

BENTLEY GLASS

THE ORIGINS OF PSYCHO-ANALYSIS. *Letters to Wilhelm Fliess, Drafts and Notes: 1887–1902.*

By Sigmund Freud; edited by Marie Bonaparte, Anna Freud, and Ernst Kris; authorized translation by Eric Mosbacher and James Strachey; introduction by Ernst Kris. Basic Books, New York. $6.75. xii + 486 pp. 1954.

During fifteen of his most creative years, Freud carried on a correspondence with a Berlin physician and biologist, Wilhelm Fliess. In these letters and work drafts, translated by Eric Mosbacher and James Strachey, the editors have chosen those items "relating to the writer's scientific work and scientific interests and everything bearing on the social and political conditions in which psychoanalysis originated. This volume contains nothing sensational, and is principally intended for the reader and serious student of Freud's published works." To such students the final section of 90 pages, entitled Project for a Scientific Psychology, which is published here for the first time in English, will be of considerable interest. In extremely condensed style it shows Freud attempting to bridge the gap between his new views on psychological behavior and his old neurophysiologic training. This effort, dated 1895, was a failure, but it brought a shift of viewpoint which led to the classic *Interpretation of Dreams* 5 years later.

Also for the general scientific reader without a special interest in psychoanalysis this book has much of value. It shows a great mind in the process of groping toward an understanding of obscure and diverse psychological phenomena. Mistaken hypotheses are followed with great glee, but as the facts of observation countermand the theory, Freud backs off, admits the error, worries over the facts and his failure to understand them, and then with a burst of intuitive insight comes closer to the truth. He tells of his sense of triumph, the great fatigue that follows a long period of intensive intellectual striving, or the occasional despair that haunts him when he finds himself isolated at the forward edge of psychological knowledge.

There is other drama in the book too, for it gradually grew apparent to Freud that his correspondent Fliess was becoming more distant as he felt Freud did not accept Fliess' own theories. This led to an eventual rupture of the relation between the two men and an end to the correspondence. The letters and notes that Freud wrote during these 15 years remain a valuable gloss to his published papers, and a striking illustration of the labor and struggle that accompanies such high achievement.

JEROME HARTZ

PRE-CORNELL AND EARLY CORNELL. *I. Agassiz and Cornell. Studies in History, No. 15.*

PRE-CORNELL AND EARLY CORNELL. *II. Letters to C. F. Hartt, First Professor of Geology at Cornell; A Cross-Section of the Agassiz Period. Studies in History, No. 16.*

By Albert Hazen Wright. A. H. Wright, 113 E. Upland Rd., Ithaca. Each vol., $1.35 (paper). (I) iv + 51 pp.; ill. (II) ii + 60 pp. + 1 pl.; text ill. 1953.

Louis Agassiz was a dominant figure in American culture for nearly three decades. His influence was so vast

that it was felt for a much longer period than the years 1846–1873, the time during which he lived and worked in the United States. Indeed, the publication of these documents relating to Agassiz's career is evidence of his continuing importance to modern scholars.

In his aspirations for the progress of science and culture, his concern with popularizing abstract knowledge, his work in improving museum practice, his training of students and his influence upon higher education, Agassiz ranks as a major individual in American cultural history. His fame as a scientist rests upon his publications in geology and paleoichthyology, work which was done before he came to the United States from Switzerland. As an American, Agassiz's lasting contributions were in the social aspects of natural science. The generations of students trained in his museum and laboratory, the many scholarly institutions established as a result of his efforts, and the professionalization of science accomplished with his help, all testify to the importance of Agassiz in American society.

A. H. Wright has published the only compilation of primary sources detailing this element of Agassiz's career which have appeared since the late 19th century. As such, his small volumes represent a significant contribution to the history of science in America. The first work (No. 15) relates to Agassiz's influence upon scientific education at Cornell University. Here are included the naturalist's Inaugural Address at the founding of the university, wherein he enunciated a modern concept of graduate education; letters he wrote to President Andrew D. White and to Henry A. Ward; and documents on the expedition of Charles Frederick Hartt to Brazil in 1870, and on the Anderson School of Natural History. The second volume (No. 16) contains 57 letters written to Hartt by various naturalists, a collection recently donated to the Geological Departments of Cornell University.

In all such documents the widespread influence of Agassiz upon American science and education is strikingly apparent. They illuminate in particular his efforts in these directions during the last ten years of his life. At a time when he enjoyed the prestige and power represented by his professorship at Harvard University and his directorship of the Museum of Comparative Zoology, he is shown in the capacity of advisor to President White, aiding the development of the natural sciences at Cornell by sending two of his outstanding students, Hartt and Burt G. Wilder, to teach at this institution, and serving as a visiting professor himself for a few years. In a period when he suffered from ill-health and might have been expected to rest content with his accomplishments of 26 years, this energetic pioneer of science is shown establishing a summer school for teachers of natural history on Penikese Island, an effort which probably shortened his life, but which began an educational innovation continued to this day.

Another revealing index to Agassiz's impact upon American culture is provided by the letters to Hartt from 17 colleagues, written during the years 1863–1874. Five of these men, Allen, Hyatt, Packard, Scudder, and Verrill, were students of the former Swiss who made their mark in the world of natural science. The letters of other correspondents, Dana, Dawson, Guyot, Hall, and Tenney, show the great influence of Agassiz's teachings upon their ideas.

In a total of 111 pages, therefore, Wright has offered meaningful sources relating to an important period in Agassiz's career. At some future time, perhaps, he will present material on the earlier years of this naturalist. The volumes themselves suffer in part from incomplete editing, commentaries which do not place the sources in their proper perspective, lack of organization, and too little attention to Agassiz's wider role in American scientific and cultural history. But these are minor shortcomings. With publications of such value, it is regrettable that they have not received larger circulation, and were not printed in quantities sufficient for their interest and importance.

EDWARD LURIE

SCIENTIFIC THOUGHT IN THE TWENTIETH CENTURY. *An Authoritative Account of Fifty Years' Progress in Science.*

Edited by A. E. Heath. Frederick Ungar Publishing Company, New York. $5.50. xvi + 388 pp. 1953.

The aim of this book is an excellent one—to trace the development of scientific concepts and the growth of new sciences during the first half of the present century. That it is not fully successful is attributable in part to the limitations of space set for each contribution and in part to the diversity of authors who were invited to contribute. Some of the writers really tried to bring out the development of concepts; some of them were satisfied with a chronological sketch; some of them mounted their favorite nags and galloped into the wings.

Among the contributions of particular interest to biologists are the following: Statistics, by R. A. Fisher; Zoology, by P. B. Medawar; Genetics, by E. B. Ford; General Medicine, by J. C. Hawksley; Social Medicine, by Alice Stewart; Neurology, by Derek Richter; Psychology, by Cyril Burt; Social Anthropology, by Meyer Fortes; and Sociology, by Donald G. Macrae. Among these, those that in my opinion best brought out the history of ideas were the contributions by R. A. Fisher, Alice Stewart, Derek Richter, and Meyer Fortes. These relatively brief essays are so thought-provoking that the reader will certainly wish each of them had been, say, half as long as this entire book. They are so promising a foretaste of what might come that the verdict on the book must be: Let's try again.

BENTLEY GLASS

CLARENCE LUTHER HERRICK, *Pioneer Naturalist, Teacher, and Psychobiologist. Trans. Amer. Phil. Soc., N. S., Vol. 45, Pt. 1.*

By Charles Judson Herrick. The American Philosophical Society, Philadelphia. $1.50 (paper). ii + 85 pp. + 1 pl. 1955.

This biography of C. L. Herrick by his brother, C. Judson Herrick, portrays the life of a truly gifted man, for C. L. Herrick was not only what the subtitle of this review indicates, but had artistic tastes and talents in the arts and humanities as well. As a scientist, naturalist, and philosopher, tributes paid him by his pupils indicate not only his greatness and place in the American scene but his warm human qualities. The late George E. Coghill (one of America's outstanding neuroembryologists), writing in 1932 in an address on Founder's Day at the University of New Mexico, said, "Professor Herrick was one of the last, if not the last, of our great naturalists—men who knew much of many sciences, including philosophy, as opposed to the specialist who characterizes science today. He was a pioneer in the sciences of the nervous system in America, and he made some of the earliest contributions on the relation of the nervous system to psychology and philosophy. He was withal a great teacher, for he not only presented facts as facts from several sciences, but gave a panoramic view of science and philosophy as a whole, in such a way that his teaching became a dynamic system, a dominating force in the life of the student." One more short quotation from Professor D. W. Johnston's tribute (Johnston was Professor of Geology at Columbia until his death in 1944) gives the breadth of C. L. Herrick's interests: "What it was that thrilled everyone who came in contact with him is difficult to say. Most of all perhaps the restless, far reaching sweep of his mind, which gave birth to memorable discussions on subjects extending the whole gamut of things physiological, psychological, sociological, . . . to say nothing of things geological and zoological."

There are three parts to this life story. The first deals with life at the midwest frontier in the upper Mississippi Valley in the latter half of the 19th Century. This is a delightful bit of history and choice elements of Americana. This and the other two parts admirably present the workings of Nature and Nurture as exemplified in the contrasting personalities of the two Herrick brothers, C. L. and C. J. In this biography are documented, in almost minute detail, the differences that existed in these two great men. To a limited degree the environmental factors operating upon them are drawn and evaluated. The older boy, C. L., was a vivacious yet serious individual, a genius with flashes of insight not present in the younger brother. This account, and others like it, will be a rich source of information to study in contrast the workings of genetics and environment. The value lies in the fact that the biographer is objective on this score and is an outstanding biologist and comparative neurologist, himself.

His own experiences interwoven with the life story of his brother, C. Judson Herrick brings to life their common aspirations, disappointments, accomplishments in their training, development and the founding of the *Journal of Comparative Neurology*. Parts II and III are entitled, respectively, The Life of Science, and Contributions to Psychobiology. In the second part a chronological account of the development of the young scientist, both professionally and spiritually, is set forth. It is the whole range, covering the short life which ended so tragically in death from pulmonary tuberculosis. C. L. Herrick, the visionary, was the second President of the University of New Mexico. Here he came in contact with several students of promise, two of whom have already been quoted.

In some naturalists there is an insatiable drive to understand the origins and meanings of behavior, especially human behavior. The last part of this biography beautifully depicts the fruition of the search C. L. Herrick found in his naturalistic approach to animal and human behavior. In this dynamic realism his equilibrium theory of consciousness holds a prominent part in his philosophy. The vivid description of the struggle with ill health and the accomplishments of C. L. Herrick should be constant inspiration to those who will read it.

The coming into being of a journal devoted to the study of the nervous system, especially slanted to point the way to a better understanding of behavior, was not only a far-sighted move but a stroke of genius. It took courage, foresight, intuition, and a gambling instinct for one man, alone, without even the promised support of papers from colleagues, to found, own, print, and publish a new journal with meager resources. In this enterprise, C. Judson Herrick had not only a ringside seat, he had a printer's composing stick in his hand also.

Here is a story almost unparalleled in the annals of science. To have sensed the "need" for such a journal, to have contributed unendingly to it, are signs of greatness. The *Journal of Comparative Neurology* is a living monument not only to Clarence Luther Herrick but will be also to C. Judson Herrick. Not only has the American science of neurology been enriched by these two men, but allied and nearby fields have been brilliantly illuminated as well. In what "might seem like a series of pitiful frustrations," C. L. Herrick launched a movement in comparative neurology and psychology that will be the bulwark in the whole field of psychobiology in years to come.

As already mentioned, this biography of C. L. Herrick is infused with autobiography by the author. It could not be otherwise. The founding, maintenance, and editorship in common of a great journal were the early works of these two brothers. Its existence since that time has been in the hands of men not only competent editors but equally inspired men of science.

PAUL G. ROOFE

THE YOUNG NATURALIST

SEASHORES. *A Guide to Animals and Plants Along the Beaches. Sponsored by the Wildlife Management Institute. A Golden Nature Guide.*

By Herbert S. Zim and Lester Ingle; illustrated by Dorothea and Sy Barlow. Simon & Schuster, New York. $1.95. 160 pp.; ill. 1955.

This volume serves equally well the young naturalist starting out on his first collecting trip and the adult observer whose interest is momentarily alerted to the wealth of life at the seashore. As a first guide, it is convenient and reasonably complete. The pocket-size makes it a comfortable volume to carry, while the 153 pages of illustrated material cover the algae, many of the more common invertebrates, some twenty dune plants, and a small number of water birds. The mollusks, perhaps because of their interest to collectors, are given the greatest coverage. Only the more conspicuous plants are mentioned, and the ducks are completely missing. Descriptions cover each species or group in general terms which will not be particularly useful in identification, but the illustrations, which are well done, counteract this deficiency. Methods for collecting are briefly mentioned, and an appendix provides the scientific names of each species illustrated. It is, however, somewhat exasperating to search the back of the volume for a scientific name which might well have been included in the initial description.

C. P. SWANSON

SEEDS OF LIFE. *The Story of Sex in Nature—From the Amoeba to Man.*

By John Langdon-Davies. The Devin-Adair Company, New York. $3.00. xx + 172 pp. 1955.

Possibly the key to this strange book can be found in its author's life history: an Englishman with a background in England and South Africa, who has been war correspondent and science correspondent for several newspapers, and chooses to live in Spain while he writes books.

The subject is certainly handled enthusiastically, and is pointed at mankind throughout. The strangeness is noted in his manner of writing: "Only when we have drunk full of wonder and mystery shall we look for clues and solutions" (p. xix), and "shizogony, shizozoites, agamogony, gamont, gamogony, gamete, syngamy, zygote, sporogony, sporozoites" to introduce alternation of generations on p. 14. He seems to strive for appeal to children, as in the chapter title: Snails and Earthworms: A Boy and a Girl in One; or in another introduction, "We come now to a higher animal, an insect. . . ." Before the child has had a chance to grow much older, he has introduced chromosome maps and sex-linked inheritance, diploids and haploids and polyploids, enzymes and hormones. The author deplores the common ignorance of human sexual anatomy and physiology, and then claims that "urine passes out in men through the penis, in women through the clitoris" (p. 132). The book lacks an index.

LORUS J. & MARGERY MILNE

MARK TRAIL'S BOOK OF NORTH AMERICAN MAMMALS.

By Ed Dodd. Hawthorn Books, New York. $1.95. vi + 242 pp.; ill. 1955.

Every youngster is probably familiar with the daily strip of Mark Trail's woodland adventures, and his natural history Sunday supplement. Although less dramatic than the lurid and fanciful comics that accompany them, the Sunday supplements in particular provide piecemeal bits of sound information handled in a convincing and understandable manner. In response to a popular demand, Mr. Dodd, creator of Mark Trail, has brought together some of his illustrated strips on the mammals of North America, and has reassembled them into a pocket-sized edition of black-and-white drawings. A commentary accompanies each page, and the contents cover the lives of 84 of the larger species. The volume should provide the young naturalist with an easy introduction to a more detailed study of mammology as he matures.

C. P. SWANSON

HORSES AND THEIR ANCESTORS.

By William A. Burns; pictures by Paula Hutchinson. Whittlesey House, McGraw-Hill Book Company, New York, Toronto, and London; American Museum of Natural History Publication. $2.75. 64 pp.; ill. 1954.

This is a book for children, and one about which only moderate enthusiasm can be voiced. Through text and illustration, the story of the horse is told in terms of ancestors, relatives, breeds and their origin, and the horse's role in past and present history. The text is simple, but often so brief as to disconnect each paragraph with that preceding and that following. The illustrations, in red, are along the margins of the pages, and opposite the paragraphs to which they refer. The format is excellent, but far superior to the book itself as educational material. For those who want a really excellent popular book on horses, the book of that name by G. G. Simpson (*Q.R.B.*, 29: 159. 1954) is recommended instead.

ECOLOGY AND NATURAL HISTORY

A FIELD MANUAL OF ANIMAL ECOLOGY AND NATURAL HISTORY.

By Cleveland P. Hickman. Burgess Publishing Company, Minneapolis. $2.25 spiral-bound (paper). viii + 125 pp. 1955.

This manual is intended to guide the field work of a semester course in elementary ecology and natural history. There are preliminary sections covering the writing of field notes and techniques of field and laboratory study. A wide selection of exercises follows, most of them falling more into the strict natural-history category, although such ecological problems as river margin and nocturnal population surveys are included. Throughout, the tone is superficial, perhaps to encourage adherence to Agassiz' dictum.

J. F. CASE

NATURE ROUNDUP.

By Robert E. Pinkerton; illustrations by Jack Bradley. Harper & Brothers, New York. $3.50. x + 246 pp.; ill. 1955.

The world around us is inscrutable to the uninitiated, even as it is sometimes to those who consider themselves thoroughly initiated, and the questions raised are more numerous than are the ready answers. Many of those that are answerable in a satisfactory fashion are raised in this volume, and the plan of the book is simply one of questions and answers. The six chapters deal with mammals, birds, fish, reptiles, the physical world, and outdoor life, and each question and answer is handled in a simple yet informative manner. There is, inevitably, a disjointedness that results from this type of presentation of material, but the favorable grouping of questions eliminates this to a certain extent. The greater part of the questions and answers is derived from the Man to Man Department of *True* magazine; the original sources of the questions, however, are those who are seeking facts from those who presumably know them, and these range from the curious schoolboy to the professional scientist. The questions, therefore, provide a measure of man's curiosity, but the reader will undoubtedly find that many of the questions he would want to have answered will not be found in this volume. This does not mean that *Nature Roundup* is inadequate; rather it is an indication that a book of this size could handle but a very small number of the possible questions which could be asked. As a reference work, it is, however, quite useful, and an index permits a ready means of determining the extent to which any subject is discussed.

C. P. SWANSON

THE VOICE OF THE DESERT. *A Naturalist's Interpretation.*

By Joseph Wood Krutch. William Sloane Associates, New York; [William Morrow & Company, New York]. $3.75. 223 pp. + 16 pl. 1954.

When an outstanding drama critic and biographer of Thoreau and Samuel Johnson resigns his teaching post at Columbia University and moves from New York City to a house on the edge of Arizona's largest forest of saguaro cactus, the outcome is scarcely predictable. Will he work on dramatic literature, write a dictionary, relax beside a mirage of Walden Pond, or just relax? An earlier book, *The Desert Year*, gave a point from which to plot an extrapolation. The present volume follows so well the same straight line that extensions of the graph will be hoped for—almost counted on.

Among other things, *The Desert Year* discussed some tantalizing problems and left them unsolved, largely for the lack of more observations in Joseph Wood Krutch's back yard. The spadefoot toad, *Scaphiopus*, had surprised him by group singing around a very temporary puddle left by a desert thunderstorm. Where did *Scaphiopus* go when there were no puddles? How did the eggs and tadpoles fare? The spadefoots were not singing for Krutch, but he heard their voices in the desert, and his current account brings the topic a notch farther—introducing to the reader a solitary spadefoot thriving on hamburger and insects in a jar on the author's desk.

Of course each partial answer introduces a hundred complete problems. But it is gratifying to have someone both curious and articulate settling down in somewhat artificial comfort on the desert, observing when he can, thinking and writing about what he sees whenever "sunbound" by day and heat (instead of snowbound by a blizzard). He watches and thinks about *Scaphiopus*, or the roadrunner bird, or Gila monsters. He compares one cactus with another in its adaptations for life where water is seldom met, and with plants that root deeply enough to reach fairly constant underground supplies. He is glad to live at a time when saguaros are more numerous as adults than as young plants, and wonders what led to greater success in germination and growth a century or two ago. All adaptations and discontinuous distributions stimulate his curiosity; the desert furnishes a wealth of examples in great variety. He has a low opinion of the scorpion's reactions but is impressed over how much more its eye is like that of mantis or man than like the inanimate soil over which its owner creeps. He affirms from observation the action of the *Pronuba* moth in a yucca flower but suggests more freedom of action than a mechanical set of instincts might imply.

The final chapter is an essay, Conservation is Not Enough, that many admired when it appeared first in *The American Scholar*. Krutch explains why the establishment of a Saguaro National Monument, the protection of Gila monsters and whooping cranes, or the cultivation of waterfowl that sportsmen like to shoot, is not an adequate approach toward the future. Conservation is too one-sided—furthering the welfare of species for which mankind shows a present interest.

It does not provide for unnoticed and non-economic species that are also ancestral to all the plants and animals of their types that can ever be. Krutch regards conservation as only an "elaborate scheming," a more intelligent exploitation. He urges an end to attempts to control nature. In its place he would see man admit and be proud of his animal origin, interested and sympathetic toward all species, anxious to fit into the ecological pattern with a minimum of disturbance for other organisms. His central question is whether man can "come to accept, not sullenly but gladly, the necessity of sharing the earth."

Sixteen pages of fine photographs by Marvin Frost and Lewis Wayne Walker will help those who have not met the Arizona-Sonoran desert in person to appreciate more easily the region for which Dr. Krutch is the present voice.

LORUS J. & MARGERY MILNE

THE CABIN.

By Walter Collins O'Kane; drawings by Francis Lee Jaques. Wake-Brook House, Sanbornville, New Hampshire. $3.50. 246 pp.; ill. 1955.

The cabin is the lookout from which O'Kane views the passing scene. It is evident that his eye is discerning, his ear attuned, his emotions and mind responsive, and his pen sensitive. From his vantage point he catches the nuances of the withdrawn, circumscribed, but constantly varying world which surrounds the cabin, and sets these down in brief paragraphs which somehow lock up for safe keeping and later reference the inspired thought, the hasty glimpse of transient beauty, and the moment of carefree peace and genuine contentment. It is not a book for a comfortable evening's reading, however; although arranged to portray the passing seasons, the mood changes rapidly from paragraph to paragraph and makes for disjointed thought. On the other hand, it is a book to be kept close by, to be picked up for a moment, opened to any page, and savored leisurely. Read in this manner, it will yield many rewarding moments.

C. P. SWANSON

WALT DISNEY'S VANISHING PRAIRIE. *A True-Life Adventure.*

By Jane Werner and the Staff of the Walt Disney Studio; based on the film narration by James Algar, Winston Hibler, and Ted Sears. Simon & Schuster, New York. $2.95. 124 pp.; ill. 1955.

The Disney natural history films are too well known and admired to require comment except to say that *Vanishing Prairie* is one of the best. A reversal of the usual Hollywood formula of book-into-movie now brings the highlights of the movie out in a form which will enable those who saw and enjoyed the film—and there are few who did not—to relive its memorable scenes in color and in text. The illustrations lose some of their clarity in reproduction, but they preserve the quality that made the movie so unique and moving a piece of cinematic art. The text, which presents the prairie in its seasonal aspects, is as direct and to the point as was the commentary in the film. The book, however, can in no way replace the film.

C. P. SWANSON

ANIMAL LIFE IN DESERTS. *A Study of the Fauna in Relation to the Environment.*

By P. A. Buxton. Edward Arnold, London; [St. Martin's Press, New York]. $4.25. xvi + 176 pp. + 14 pl.; text ill. 1955.

Particularly welcome is this reprint of Buxton's *Animal Life in Deserts*. It remains, in spite of its 32 years, a valuable introduction to the desert environment, whose rigors exact from its inhabitants minor adaptive miracles if they are merely to exist. Chapters on climate, the physical environment, and the flora precisely define this hostile environment. How animals manage to exist under such conditions is the final topic, which includes a stimulating, if destructive, analysis of the theory of protective coloration as it has been applied to desert dwellers.

J. F. CASE

FREAKS AND MARVELS OF INSECT LIFE.

By Harold Bastin; drawings by Jane Burton; foreword by Frederick Laing. A. A. Wyn, New York. $3.75. 248 pp. + 21 pl.; text ill. 1954.

Intended to be a layman's introduction to insects, this book succeeds only in engendering a degree of awe at insect resourcefulness without improving our knowledge of entomological fundamentals. There are a few introductory pages of anatomical and physiological information which suffer in clearness from the lack of illustrations. The remainder is given over to innumerable examples of mimicry and of the interrelationships of insects with plants and men. A few such are instructive, but the rest, while themselves interesting, contribute little to the advancement of the subject. Harold Bastian obviously has an immense knowledge of entomology upon which he has drawn heavily to fill his pages with rare examples of insectan chicanery, e.g., the South American mantid whose stercotaceous appearance provides it a comfortable living at the expense of flies which incautiously approach an apparently highly nutritious bit of excrement. *O tempora! O mores!*

J. F. CASE

THE BIOLOGY OF THE AMPHIBIA.

By G. Kingsley Noble. Dover Publications, New York. $4.95. xvii + 577 pp. + 1 pl.; text ill. 1955.

The younger "generation" of herpetologists and biologists who have any laboratory use for salamanders and frogs will welcome this unabridged republication of a book which first appeared in 1931 but has long been out of print. G. K. Noble, late Curator of Herpetology and Experimental Biology at the American Museum of Natural History, was peculiarly fitted for this work by being fundamentally a naturalist, and by supplementing that basic interest with research into amphibian phylogeny as evidenced by their patterns of development.

The Biology of the Amphibia is intended explicitly to be "a general textbook which summarizes the relations of the Amphibia to one another and to their environments," with avoidance of technicalities where possible, and with the inclusion of "much which should be of interest to the field naturalist or traveler," (quotations from the author's Preface). There are chapters on the ancestry of the Amphibia, on their ontogeny, speciation, and adaptation, on each of their organ systems treated comparatively, on their ways of life and instinctive behavior, on their geographic distribution, all filled with fascinating information, much of it collected in one place for the first time. The selection of useful and meaningful material and the readable style of presentation hold the reader's interest throughout even such parts as the one entitled Relationships and Classification. Sources of the information are given in the text, and a bibliography up to 1931 follows each chapter. There is a constant and very sensible analysis of adaptations in relation to natural selection, without, however, stretching the theory too far; the author points to many modifications the maintenance of which cannot be readily explained in such terms alone.

Inevitably, many of today's specialists will find inaccurate details, but these will be far outnumbered by aspects of amphibian adaptation which he will find new, such as, "little frogs as a rule do not climb big trees." It is regrettable that there are no colored illustrations of the specimens, and that the drawings of the animals have no indication of the scale.

The Table of Contents has a comprehensive listing of the subheadings within each chapter. The 32-page index would seem sufficient at first glance, but, for example, some interesting information on cave salamanders in the text is not listed in the index under "cave" or "blind," but only under the taxonomic names of the specific cases cited.

The Dover Press is to be thanked for this republication, among others, but it is sincerely regretted that G. K. Noble died too young to get out a revised edition. This kind of book is needed by students beginning to specialize, in order to counteract the tendency to lose sight of the organism as a whole. Perhaps this republication will inspire other naturalists to undertake similar books for their groups of organisms.

E. L. WHITE

SALAMANDERS AND OTHER WONDERS. *Still More Adventures of a Romantic Naturalist.*

By Willy Ley; illustrations by Olga Ley. The Viking Press, New York. $3.95. x + 293 pp.; ill. 1955.

Willy Ley is always interesting and remarkably accurate as a popularizer of science. However, *Salamanders and Other Wonders* does not attain the high level of interest of *The Lungfish, the Dodo, and the Unicorn*, in which the assortment of organisms was more familiar to most readers.

This book's real contribution is made by directing biologists' attention to the wealth of natural history, of varying degrees of accuracy, to be found in journals of voyages of exploration, some dating from the 15th and 16th centuries, the more complete records dating from the 18th and 19th centuries. From this historical research Willy Ley presents or collects pertinent material on partially or completely legendary lethal trees, the coco-de-mer, centuries-old tortoises, etc., as well as evidence on the near-extinction of some birds and sea otters, and the existence of some fearful hairy "men" above the snow-line in the Himalayan Mountains. The range of his interests seems unlimited; any question of authenticity sends this "romantic naturalist" off on the scent. Many younger biologists will find interesting the account of Paul Kammerer's salamander and toad which purported to demonstrate, at least to the satisfaction of the Soviet Academy of Sciences, the heredity of acquired characteristics, but any biologist will find Ley's analyses of Darwin's and Lamarck's contributions to evolutionary theory rather weak.

It is difficult to be sure for whom this book is designed. It collects many stories which most biologists know as the lore of their own fields, but which are of exotic, if any, interest to the non-biologist. Some of the technical details necessary to grasp the significance of controversial points are beyond the general reader. It definitely has a place on the shelf of light, interest-arousing outside reading for students of general biology.

E. L. WHITE

DESERT RESEARCH. *Proceedings International Symposium Held in Jerusalem, May 7–14, 1952, sponsored by The Research Council of Israel and The United Nations Educational, Scientific, and Cultural Organization. Res. Coun. Israel Spec. Pub. No. 2. Patron: Dr. Chaim Weizmann, President of the State of Israel.*

Interscience Publishers, New York. $6.00 (paper). xii + 641 pp. + 1 map; text ill. 1953.

The symposium on desert research, sponsored by UNESCO and the Research Council of Israel, was held in Jerusalem in May, 1952. This volume contains the papers presented there. Four introductory lectures by Leighly, Kellogg, Monod, and Bagnold cover some 90 or more pages, and these are followed by a large number of briefer papers dealing with the climate, biology, soils, water, and energy of the desert. A short group of general lectures lies interspersed among the more detailed and technical reports. Clearly this is applied and basic science of a special and highly intricate nature, but its importance can be judged by the stakes involved, i.e., the effective utilization of vast arid lands by an ever-demanding and expanding population. The answer to the many problems is, of course, water, and its availability and utilization underlie every topic discussed. In so far as Israel itself is concerned, the urgency for information is great, but even greater, apparently, is the paucity of technically trained personnel to initiate steps in arid land occupation that are already planned and needed. A wealth of detailed material is brought together in this volume; the years ahead will tell to what extent this information is put to work productively.

DEEP-SEA RESEARCH. *Volume I, Number 1, October, 1953.*

Editors, L. Fage, Cameron D. Ovey, and Mary Sears. Pergamon Press, London. £4. 10s. subscription per volume. Quarterly. (1) 64 pp. + 3 pl. + 1 map + 3 charts. 1953.

The first copy of this oceanographic journal contains two articles of biological nature: Rôle des Flagellés calcaires dans la fertilité et la sédimentation en mer profonde (F. Bernard); and The significance and diatom content of a deep-sea floor sample from the neighbourhood of the greatest oceanic depth (J. D. H. Wiseman & N. Ingram Hendey). Among other articles, there are notes on the soundings of the recently discovered great deep in the Marianna Trench, which is very close to 36,000 feet deep. Diatoms collected from about 5 miles away in the Trench show strong indications of wear and tear, produced probably by solution. The periodical is excellent in style and printing, with fine plates and charts; and the members of the Editorial Advisory Board include the most notable oceanographers of Europe, Great Britain and the Commonwealths, and the United States. It is to be edited jointly by a Frenchman, an Englishman, and an American woman.

THE SUN, THE SEA, AND TOMORROW. *Potential Sources of Food, Energy and Minerals from the Sea.*

By F. G. Walton Smith and Henry Chapin. Charles Scribner's Sons, New York. $3.50. xiv + 210 pp.; ill. 1954.

The vast, untapped, but very dilute nutritional and mineral resources of the world's oceans cannot take care of "tomorrow's" population demands for food, raw materials, and living standards (judging from present rates of their increase), but wise exploitation of the sea may help to reduce the deficit. Here an oceanographer (Dr. Smith is also Director of the Miami University Marine Laboratory) discusses in non-technical language some of the complex balances, biological and economic, which must be considered in the development of projects to get more fish, more plankton, more minerals, and more power from the seas. Present methods are comparable to those of man's hunting civilizations on land.

The book is not overloaded with data and makes no pretense of giving enough information to answer the problems it suggests. It is fundamentally a plea for more knowledge, more oceanographers, and more support of research into development, cultivation, and collection of materials needed from the oceans. It is written more for the voter and public and private administrator than for biologists, but most "land-lubbers," biologists included, can find much of interest. It should be added to each teacher's growing list of recommended reading in general biology, if for no other reason than that it dramatizes the practical aspects of food pyramids, and makes sober distinctions between materials present and available, and between renewable and non-renewable resources.

E. L. WHITE

EVOLUTION

SYNTHETISCHE ARTBILDUNG. *Grundlinien einer exakten Biologie. Volumes I, II.*

By Heribert Nilsson. Verlag CWK Gleerup, Lund. S. Kr. 250.—(cloth); 225.—(paper). (I) Pp. 1–734; (II) pp. 735–1303; ill. 1953.

The belief that evolution has taken place is now so widespread among scientists, and the evidence in favor of evolution appears so overwhelming to nearly all biologists who have studied it, that the appearance of a treatise by a reputable and experienced biologist which raises an argument against the concept of organic evolution comes as a distinct surprise and shock. In reading the present volume, I have found myself repeatedly wondering how such a thing could come to pass in this day and age. Heribert-Nilsson is neither a young upstart nor a fundamentalist "crank," but a well-known geneticist who retired from his professorship only a few years ago after a lifelong career of interesting and valuable research on hybridization and the species problem in willows. There is good reason, therefore, to read his treatise carefully, and to consider his evidence seriously.

The evidence presented is very extensive, and covers all pertinent fields of biology. Although it is presented in German, the English-speaking reader who is not prepared to wade through more than 1100 pages of technical German can learn the main arguments from the 100-page English summary presented at the end of the second volume.

After going through all of this "evidence" in a cursory fashion, and after studying parts of it in detail, I find it myself to be a curious mixture of accepted facts, half-truths and misinterpretations. The more than 1200 scientific papers and books cited in the literature list are nearly all by well-known biologists and paleontologists, and represent a good cross-section of the literature on genetics, paleontology, and other phases of evolution from Darwin to the present. After devoting 188 pages to a review of the literature on mutations, the author reaches the conclusion that both spontaneous and experimentally induced mutational changes result chiefly from a chimaeric condition of the somatic tissues, and are therefore a byproduct of cell differentiation. Recognizing that most mutations produce harmful or lethal effects, he asserts that no new mutations have a positive selective value. This assertion, although repeatedly made, is not in accord with the facts, as can be learned from any unbiased review of the subject. Mutations with slight effects on the phenotype are considered not to exist, and evidence in favor of such mutations, which many evolutionists consider to be of prime importance to their problem, is branded as "Lamarckism." Polyploidy, also, is rejected as a factor in the origin of species, and the author reaches the curious conclusion that all allopolyploids are either cultivated plants or weeds, which could not have arisen without the intervention of man.

A more detailed consideration of the way in which Heribert-Nilsson reaches this conclusion concerning allopolyploids or amphidiploids is perhaps worthwhile, since it illustrates the type of thinking which prevails throughout the book. After mentioning two synthetic amphidiploids, *Raphanobrassica* and *Nicotiana rustica-paniculata*, he cites three examples of natural amphidiploids which have been reconstituted experimentally, *Galeopsis tetrahit*, *Brassica napus*, and *Salix cinerea*. He considers these to be the only "certain amphidiploids" that are known, and points out correctly that all three of these species are closely associated with man, and might disappear from the earth if man became extinct. He makes no mention, however, of the numerous examples of wild, non-weedy species the amphidiploid nature of which is supported by strong circumstantial evidence, such as *Penstemon neotericus*, *Zauschneria californica*, *Iris versicolor*, *Drosera anglica*, *Bromus carinatus*, *Agropyron parishii*, and *Elymus glaucus*. He does, however, mention several probable amphidiploids listed by Tischler, all of which are weeds. It is, of course, true that many amphidiploids, and particularly those which have originated so recently that their ancestry is easily determined, are weeds or cultivated plants. This would be expected on the basis of the widely accepted theory that amphidiploids are most likely to be successful in regions newly available for colonization by plants, since the majority of new habitats which exist today are those opened up by man. Heribert-Nilsson, therefore, reaches his conclusion in this as in other instances, by making positive generalizations on the basis of only part of the evidence available, and by neglecting completely the strongest evidence against his point of view.

The author finishes his review of genetic evolutionary processes with a discussion of species hybridization, including a detailed account of his own experiments on complex hybrids in willows, the genus *Salix*. He demonstrates that most of the products of complex hybridization are highly sterile, and that even types which initially appeared to be constant, fertile, and equipped with all of the morphological and genetical characteristics of valid new species broke down in later generations through the appearance of weak or sterile genotypes. From this demonstration he concludes that the formation of new species as a result of interspecific hybridization is impossible.

I am not surprised at Heribert-Nilsson's results. I would have been much more surprised if a single scientist in his own lifetime could synthesize a new species in a genus of long-lived woody plants like *Salix*. The limited success which was obtained in this direction suggests that, given the thousands of hybridizations between *Salix* species which have probably occurred in nature, the countless millions of seeds which the fertile hybrids have produced, and the hundreds of thousands of years over which hybrid products have had opportunities to invade a great variety of ecological niches, the combination of a vigorous, fertile hybrid population and an environment to which this population was suited could have occurred several times during the history of the genus.

Leaving genetics, Heribert-Nilsson devotes more than 300 pages to a discussion of the paleontological evidence for evolution. Here he is disturbed first by the admittedly large gaps in the fossil record, and second, by the fact that some groups which according to Hofmeister's concepts of plant evolution should be relatively advanced, actually are known from geologically very ancient strata. His arguments against the validity of the fossil record have been answered by a number of paleontologists, particularly in the more recent books by G. G. Simpson, which Heribert-Nilsson does not cite. Most modern students of the fossil record recognize the facts that gaps exist exactly in that part of the record about which we would like to know the most, namely, the transition between classes and other major categories; that evolution has proceeded at very different rates in different groups of organisms, and even

within the same evolutionary line at different times in its history; and that the evolutionary "tree" has been so highly branched and "shrub-like" that modern orders and classes can by no means be arranged in a linear evolutionary sequence, as Heribert-Nilsson does in his Fig. 9. Simpson and others have given good reasons for these facts, and have shown that they by no means can be used as evidence against evolution.

The author finishes his discussion of paleontology with the astonishing hypothesis that the fossil floras of the world do not consist of associations which lived together in the same habitat, but of miscellaneous assemblages which were brought together from all corners of the earth by means of tremendous tidal waves. He accounts in this manner for the fact that many fossil floras, such as that of the London Clay, consist of species whose modern relatives live in tropical countries far removed from the site of deposition. Among the numerous objections to such an hypothesis two may be briefly cited here. One is that the tropical character of the fossils found in regions which now support only temperate biota is not confined to terrestrial forms, but exists also in respect to corals, molluscs, and other marine types. Furthermore, the marine and terrestrial forms are not usually found mixed together, but occur in different deposits. According to Heribert-Nilsson's view, therefore, we should have to postulate some world-wide tidal waves which carried only terrestrial biota, and others which confined their attention to marine forms. The second objection is that, as Chaney has pointed out, even the early Tertiary floras are zoned in relation to latitude, with floras having a more tropical character appearing in all parts of the northern hemisphere at lower latitudes than those of a more temperate character. Chaney has correctly pointed out that this situation can be explained only on the assumption that the plants grew in the places where they were fossilized, and that during the early part of the Tertiary period the equator, the poles, and the continents had the same position relative to each other as they do at present.

Heribert-Nilsson's final line of "evidence" against evolution consists of an attempt to criticise certain basic principles of genetics, particularly the linear order of the genes on the chromosomes. In this attempt, he dismisses as "confusion" the long series of exact predictions and verifications through carefully controlled experiments which have led to the discovery and integration of such phenomena as double crossing over, interference, structural alterations of the chromosomes, and position effects. This section of the book leaves one with a particularly strong impression that the author is criticising work which he does not understand.

The last part of this remarkable work is devoted to the author's own substitute for organic evolution. This is not, as one might at first assume, a reversion to the doctrine of special creation, but a new theory which he calls "emication." This states that at various periods in geological time, violent revolutions have destroyed all of the earth's biota, only to have living forms reconstituted by a sudden coming together of organic molecules to form gametes possessing the capability of developing into some highly complex form, such as a pine tree, an elephant, or a man. About this hypothesis the writer need make only one comment. If any evidence were needed to show how firmly rooted in biology is the modern concept of evolution, Heribert-Nilsson's book helps to provide such evidence by the absurd lengths of fantasy and misconception to which he must go in order to produce a scientific "denial" of this phenomenon.

G. LEDYARD STEBBINS

THE MAJOR FEATURES OF EVOLUTION.

By George Gaylord Simpson. Columbia University Press, New York. $7.50. xx + 434 pp.; ill. 1953.

In 1945 I reviewed at considerable length the precursor of the present book, which was published in the preceding year with the title *Tempo and Mode in Evolution* (*Q.R.B.* 20: 261–263). Even as extensive a reworking as the book has now undergone cannot give it quite the impact of the original, considerably smaller work—for in 1944 *Tempo and Mode* represented the first revolutionary attempt of a great paleontolcgist to apply to the data, concepts, and theories of his field the new viewpoints which had come into evolutionary theory through the impact of modern genetics. The relation between the present work and its forerunner is therefore rather like the relation between the first edition of E. B. Wilson's great classic *The Cell in Development and Heredity* and the monstrous, overwhelming Third Edition which so many of us had to study as students and could admire but never fully assimilate. Simpson has not gone so far as the Third Edition yet, but one may justly tremble at the prospect.

What has just been said is not in any way intended to denigrate the present work. It is of major importance. It develops far more fully than *Tempo and Mode* the original aspects of the author's thought. Previously untenable positions have been carefully re-examined. There is now only a minor spot for "quantum evolution," and the relations between bradytelic, horotelic, and tachytelic rates of evolution are made far clearer than before. New examples have in places been substituted for old. The general emphasis of the work also seems to have shifted somewhat, away from the demonstration of the applicability of genetic concepts to paleontology toward the further consideration of the evolution of adaptation through the interacting evolution of environment and organism. The book, naturally enough, exhibits also the fruits of the analytical labor and the thinking that have gone into his other books and papers written since *Tempo and Mode*, in particular

The Meaning of Evolution and *Horses*; and also of the rich harvest of evolutionary theory and discussion of the past decade by Rensch, Dobzhansky, Zimmermann, Schmalhausen, Schindewolf, Stebbins, by the numerous contributors to symposia on evolution (including the outstanding Princeton Bicentennial Symposium of 1949 which Simpson himself helped to organize), and by contributors to the new journal *Evolution*, founded in 1947.

One may be sure that this book will exert a vast and steadily increasing influence upon modern biology. There are few indeed in the present day who can master such a diversity of disciplines, knit them together into a coherent frame of theory, and present them with such mastery alike of example and principle. Graduate students of biology *must* in the future study this book if they are to be properly trained. Anyone who ventures into evolutionary studies or discussions without an intimate knowledge of what is here set forth will quickly make a fool of himself.

BENTLEY GLASS

EVOLUTION. *Symposia of the Society for Experimental Biology, Number VII.*

Academic Press, New York. $7.80. xx + 448 pp. + 4 pl.; text ill. 1953.

This British symposium on evolution contains 24 contributions on a great variety of subjects. While it lacks the homogeneity and freshness of the famous Princeton symposium on the subject in 1949, it provides a number of analytical essays on the nature of evolutionary factors and their interactions, and a still larger number of interesting examples of evolutionary trends and developments in particular groups.

The other papers are prefaced by a characteristically stimulating review of the symposium by J. B. S. Haldane, and are rounded off by a Postscript from one of the editors of the volume, J. F. Danielli, who has some penetrating remarks to make about the deductions which should or should not be drawn from the presence of many complex organic molecules in the metabolism of an extensive array of animals (and plants, one might add); and some further thoughts on the chemical evolution of genes and the relation of physiological adaptation to evolution. Between these starting and end points the coverage ranges from theorizing about the chemical origin of life and the steps of biochemical evolution (Pringle; Baldwin) to Social Behaviour and Primate Evolution (Chance & Mead). Hinshelwood and Demerec presented quite divergent ideas about the alterations of bacterial populations, the former emphasizing wholesale adaptation of populations, the latter the transformation of populations by the selection of spontaneous or induced mutations. D. G. Kendall added a mathematical study of stochastic processes in the growth of bacterial colonies, designed to distinguish between the effects of mutational and adaptive events. Two significant papers of a theoretical nature were contributed by Mather and by Thoday. Mather made an excellent review of The Genetical Structure of Populations, the principal defect in which was his failure to indicate the similarity or identity of forces and situations he discussed with those examined under different terminologies by such notable evolutionists as Schmalhausen and Sewall Wright. Thoday's analysis of Components of Fitness will strike many readers as being about the most penetrating analysis of fitness yet set down on paper.

Next follow 4 contributions which treat of evolution in particular plant groups or of plants in particular kinds of environment: Race Formation and Reproductive Method in Flowering Plants (H. G. Baker); Species Differences in *Primula* (D. H. Valentine); Evolutionary Trends in an Equatorial Climate (R. E. Holttum); and The Cytological Evolution of the Fern Flora of Ceylon (I. Manton). Polyploidy and hybridization are evidently even commoner in tropical ferns than among other plants. The effects of a uniform climate on the physiology of plants offer new kinds of problems for the study of ecotypes. With the 2 papers on the genetics of closely related species, subspecies, or geographical races of plants mentioned above there may be grouped 2 similar papers on the same types of situations occurring in animal speciation (Steven; Spurway), and a group of papers by Hovanitz, Sheppard, and Dowdeswell and Ford on polymorphism in the Lepidoptera.

Discussions by Waddington of Epigenetics and Evolution and by Medawar of Some Immunological and Endocrinological Problems Raised by the Evolution of Viviparity in Vertebrates take the reader into the realm of the relation of genes to developmental processes and of developmental processes in turn to the channeling of evolutionary change. The papers by M. J. Heuts on Regressive Evolution in Cave Animals, by S. M. Manton on Locomotory Habits and the Evolution of the Larger Arthropodan Groups, by E. N. Willmer on Determining Factors in the Evolution of the Retina in Vertebrates, and the already mentioned essay on the relation of social behavior to primate evolution consider other types of internal and external factors that serve to restrict and channel the course of evolutionary development in particular groups. The paper by S. Manton deserves particular mention as a novel and exceedingly intriguing type of evolutionary study.

Like all volumes in this series, this one is exemplary in editing and format, with one exception—the lack of an index. Such a deficiency unavoidably brings about a grave limitation in the use of the book subsequent to a first reading. The editors can scarcely be excused for permitting it.

BENTLEY GLASS

INTRODUCTION TO EVOLUTION.

By Paul Amos Moody. Harper and Brothers, New York. $6.00. xii + 475 pp.; ill. 1953.

There is, at the present time, no elementary college textbook of evolution which excels this one. In regard to level, this treatment should be intelligible even to students whose background in general biology is rudimentary. Most of the necessary background of information is supplied as each new subject is taken up. This inclusion necessarily keeps the discussion from getting very deep into any aspect of the subject, but the comprehensive character of the treatment provides a genuine survey of the subject.

The first chapters deal with the evidences of the existence of organic evolution, in a treatment that might be said to resemble Darwin's own brought up to date: evidence from the structure of modern animals, from embryonic development, from chemical structure and metabolism, and from serological tests. Five chapters are then devoted to the geologic record and the story of life as reconstructed from fossils. Two chapters deal with the geographic distribution of animals on continents and oceanic islands. Next comes a chapter on the relation of taxonomic classification to evolution. The final major section is devoted to the nature of evolutionary change, that is, to population genetics, natural selection, and other factors. The final chapter is an unusual Open Letter to Students, which speaks frankly of the impact of evolutionary thought on religious and philosophical concepts and gives some excellent advice.

The book is well illustrated and indexed, and each chapter is followed by a short list of selected references. The author gives evidence of having a full acquaintance with the many important books and a wide sweep of the periodical literature published in the field of evolutionary studies in the past 20 years. The facts and examples cited are unusually accurate, and give evidence of critical care. On certain controversial matters, such as the erect stature of the australopithecine apes, the author has been swayed too greatly by over-enthusiastic proponents of their near-human status.

If any criticism at all is warranted in the case of a book so admirably adapted to its intended level of instruction, it is possible that the deferment of any consideration of the mechanisms of evolutionary change and the nature of evolutionary processes to the end portion of the book may militate against the proper understanding of evidence and historical change at the time when those topics are studied. Personally, I prefer to teach the elementary course in evolution the other way about, first analyzing the factors of evolutionary change and then providing an illustration of their interplay in the evidences and historical changes. But this is probably a minority view, and most teachers will prefer the sequence of subjects chosen by Moody.

BENTLEY GLASS

EVOLUTION AND GEOGRAPHY. *An Essay on Historical Biogeography, with Special Reference to Mammals, Condon Lectures.*

By George Gaylord Simpson. Oregon State System of Higher Education, Eugene. $1.00 (paper). 64 pp.; ill. 1953.

This publication is an expansion of two lectures, given in January 1953 at the University of Oregon, into 6 chapters entitled: Introduction to Biogeography; Isolation and Migration; The Composition of Mammalian Faunas; The North American Mammalian Fauna; Faunal Resemblances; and Faunal History and Earth History. Relatively non-technical in style and abundantly illustrated with pictures and diagrams, this is an invaluable short course on an aspect of evolution in regard to which the author is unquestionably one of the greatest living authorities.

BENTLEY GLASS

THE PERMIAN REEF COMPLEX OF THE GUADALUPE MOUNTAINS REGION, TEXAS AND NEW MEXICO. *A Study in Paleoecology.*

By Norman D. Newell, J. Keith Rigby, Alfred G. Fischer, A. J. Whiteman, John E. Hickox, and John S. Bradley. W. H. Freeman & Company, San Francisco. $7.50. xx + 236 pp. + 32 pl. + 4 folded charts; text ill. 1953.

"This study is a collaborative effort to deduce something of the environmental conditions which led to deposition of the celebrated Permian reefs of the Guadalupe Mountains area of western Texas and southern New Mexico, some of which are among the most extensive and best-displayed fossil organic reefs." This attempt of the joint authors has become a brilliant success. Under the planning and guidance of N. D. Newell, one of the most stimulating and fascinating pieces of work has been brought forth that has ever been published in the fields of geology and paleontology during recent years. Intensive stratigraphical, petrological, and paleontological studies have been undertaken and have resulted in a comprehensive and many-sided picture of the environmental and ecological conditions of the reef complex.

Three geologic provinces in the area are to be distinguished: (1) the Delaware Basin with fine-grained sandstones, siltstones, and sandy limestones, stratified in thin laminations resembling varves, in most places with siliceous spicules of sponges and probable plant spores only; (2) the rim of the basin, occupied by organic reefs and banks of light-colored, massive limestone and dolomite, with rich, well-preserved silicified faunas (calcisponges, algae, bryozoans, brachiopods); and (3) a shelf area containing light-colored, thin-bedded dolomite, sandstone, and evaporites with an impoverished fauna. This association of marginal reefs

and stagnant basins finds its counterpart in the Mississippian reefs in the North of England, the Permian reefs of East Greenland, and the Upper Triassic ones of the Tyrol. It is thus a typical phenomenon governed by similar ecological features.

A systematic study of the rich faunas of the Permian rocks will be published later. For the present, in a short chapter and several tables, a survey of the known ranges and distributions of species is given. Three plates present figures of some fossils, showing their excellent state of preservation, especially of the internal characters. Further chapters deal with the diagenesis (migration of solutions, silicification, dolomitization), the paleoecology of the Permian rocks, and the Permian reef oil. In a restricted review it is impossible to give even a partially adequate idea of the rich contents of the book. A special mention is deserved by the very rich, instructive illustrations in the form of text-figures and 32 excellent collotype plates demonstrating outcrops, fossils, and thin-sections of rocks. It must be repeated: the book is, in every respect, a standard work, for which the authors as well as the publishers are to be heartily congratulated.

O. H. SCHINDEWOLF

LOWER LEONARDIAN BRACHIOPODA OF THE SIERRA DIABLO. *Bull. Amer. Mus. nat. Hist., Vol. 105, Art. 3. By Francis Greenough Stehli. American Museum of Natural History, New York.* $1.75 (paper). Pp. 257–358 + 11 pl.; text ill. 1954.

The Sierra Diablo Mountains together with the nearby Guadalupe Mountains of western Texas form the classical ground for our knowledge of the North American Permian. The excellent outcrops of Leonardian rocks in the Sierra Diablo region have permitted a very detailed study of the complex facies changes at the margin of the Delaware Basin and have given an unrivalled opportunity of sampling very rich faunas of beautifully preserved silicified fossils.

Introductory chapters concern the stratigraphy, the lithology, the different facies of the Permian reef complex, and a comparison with modern reef. A striking difference consists in the remarkable fact that the Permian reefs are connected with stagnant basins of deposition, whereas modern reefs are found in well-aerated environments. Moreover, they are constructed mainly by sponges, algae, and subordinately by Bryozoa. Brachiopods occur in considerable numbers, but without playing a noteworthy role in the construction of the reefs.

Remarks on brachiopod adaptations and their different modes of attachment form a transition to the main part of the work, which is devoted to the systematic description of Brachiopoda. The excellent preservation of the silicified material, which was gained in large numbers by a solution of the limestones in hydrochloric acid, permitted a more complete and intensive study than has previously been possible. There are described 54 species, 36 of which are new, distributed among 45 genera (12 new), 14 subfamilies (6 new), and 15 families (4 new). A classification above the level of superfamilies has not been attempted, since the old ordinal taxonomy by Beecher has now proved to be unsatisfactory. The descriptions are very thorough and with due consideration of variability. But sometimes the reviewer has the impression that the author is going too far in the splitting of genera, especially among productids. More than 100 genera have already been proposed for this comparatively small and closely allied group. They, and even the "families," are based on subordinate differences of sculpture; species-groups and at most subgenera would appear to be sufficient for their expression. Valuable schematic text-figures and remarkably good plates illustrate this very important paper.

O. H. SCHINDEWOLF

FOSSIL PLANTS OF THE FLORISSANT BEDS, COLORADO. *Contributions to Paleontology. Publication 599. By Harry D. MacGinitie. Carnegie Institution of Washington.* $5.25 (paper); $5.75 (cloth). iv + 198 pp. + 75 pl. 1953.

The Tertiary beds of Florissant, Colorado, need no introduction to the paleontologist, but despite its known richness in plant and insect fossils, no comprehensive account of the flora has been attempted since Lesquereux did this in 1883. Since much of what Lesquereux described is incorrect, the need is obvious. A good portion of the monograph is given over to systematic descriptions and half-tone plates, but an excellent preliminary section deals with the composition of the flora and its modern relationships, and with the relation of the Florissant beds to other collecting areas. Plant geographers and ecologists as well as paleontologists will find much that is useful in this volume.

FOSSIL AMPHIBIANS AND REPTILES. *By W. E. Swinton. British Museum (Natural History), London.* 5s. (paper). xiv + 114 pp. + 17 pl.; text ill. 1954.

The British Museum has for several years been issuing a series of lively, well-illustrated handbooks as adjuncts to the exhibits in that institution, and as general guides to the subjects illustrated by those exhibits. The new guide to the fossil amphibians and reptiles by W. E. Swinton is one of the recent additions to this series. It provides a concise account of the extinct amphibians and reptiles that should be very useful to readers

interested in this particular facet of paleontology. Written for general reading, in Swinton's usual clear style, it is therefore easily comprehended by the laymen. And since this book is written with a minimum use of the technical terms that form the special vocabulary of vertebrate paleontology, the volume should be particularly helpful as a reference work for zoologists and paleontologists who are not specialists on fossil vertebrates.

The book follows the usual pattern for a work covering this subject. After a simple, introductory account of the vertebrates, it takes up the problem of amphibian origins, and proceeds to descriptions of the extinct amphibians and an account of their evolution. This leads to a discussion of the origin of reptiles from the amphibians. Then follows a series of chapters dealing with the various groups of reptiles, with particular emphasis on those that were dominant during late Paleozoic and Mesozoic times. The text ends with a discussion of the always interesting and thorny problem of extinction. There is a synoptic classification and a glossary in the back of the book.

The book is illustrated with figures which apply especially to specimens on exhibit in the Museum, and some of which, for this reason, are not as complete as might be desired. There are also plates, among which are some very interesting restorations by Maurice Wilson, an artist who has distinguished himself recently by his excellent drawings of extinct animals done in a delightfully charming style.

EDWIN H. COLBERT

LIFE ON OTHER WORLDS. *Second Edition, Reprinted. By Harold Spencer Jones. English Universities Press, London; [The MacMillan Company, New York].* $3.00. xii + 259 pp. + 17 pl. 1952.

This is the 2nd edition of a book which, with clarity and sound scientific reasoning, appraises the possibility of life existing on other planets. The basic assumption is that where conditions are suitable life will eventually come into being. Since the possible elements are limited in number, the number of planets almost countless, and ample time available, the probability of life elsewhere is high, in Sir Harold's opinion. The probable existence of a Martian vegetation is in support of this conclusion, as do astronomical observations which indicate that suitable atmospheres and temperatures are found on other planets. Whether Sir Harold is correct in his basic assumption that life will arise if the circumstances are favorable cannot, of course, be proved; but the thought of other living worlds will be both comforting and fearful as our scientists ready their plans and instruments for the invasion of interstellar space.

C. P. SWANSON

GENETICS AND CYTOLOGY

ADVANCES IN GENETICS. *Volume V. Edited by M. Demerec. Academic Press, New York.* $8.50. viii + 331 pp.; ill. 1953.

The quality of these volumes seems to be steadily improving. The coverage of important genetical subjects is being extended with each volume, the critical quality of the reviews is at a high level, and the contributors are all outstanding in their respective fields of work. The series has quickly become the most indispensable of publications in genetics.

Volume 5 contains six reviews. The first, by W. Frank Blair, deals with Population Dynamics of Rodents and Other Small Animals. Although ecological rather than genetical in substance, the discussion is pointed at those aspects of population dynamics that are of particular interest to the geneticist, and foreshadow a day when genetics and ecology will be more closely integrated than at present. E. B. Ford has contributed a review on The Genetics of Polymorphism in the Lepidoptera. It is an excellent summary of his views of the genetic basis and evolutionary significance of balanced and transient polymorphism. Coming from the leading student in the world of these phenomena, it will long be consulted, even—perhaps especially—by those who disagree with him either in detail or in principle. A. D. Hershey's review of Inheritance in Bacteriophage is only 18 pages in length, including two pages of references. It is nevertheless quite the best introductory survey of the subject I have seen, being not only succinct but also lucid and comprehensive. G. Pontecorvo's monographic treatment of The Genetics of *Aspergillus nidulans* is on the contrary exhaustive in nature. Written with the help, in particular sections, of his collaborators J. A. Roper, L. M. Hemmons, K. D. MacDonald, and A. W. J. Bufton, it treats most comprehensively the life cycle, methods of culture, isolation of mutants, methods of genetic analysis (including heterokaryosis, crossing, recombinant selection, and perithecium analysis), the formal genetics (including identification of loci, linkage relations, pseudoallelism, and physiological genetics), and a study of diploids and mitotic recombination. Unlike most of the other contributions to this series, which are reviews of published work, this genetic monograph consists very largely of unpublished material, a fact which makes it ten-fold more valuable. It is highly praiseworthy to have brought together in one place virtually all that is now known about the genetics of the first homothallic mold to be subjected to genetical analysis.

Finally, and by no means least important, Volume 5 contains two very significant contributions by Japanese investigators. Hideo Kikkawa has reviewed the Biochemical Genetics of *Bombyx mori* (Silkworm); and Yoshimaro Tanaka has covered the formal Genetics of

the Silkworm, *Bombyx mori*. Each of these reviews discusses for the first time in a European language a great deal of important work that up till now has been known only to those who can read the Japanese language. The biochemical work offers many examples of gene-controlled chemical reactions to place beside those of *Neurospora crassa*, *E. coli*, and man. In particular, the problems relating to tryptophan metabolism are elucidated. The formation of pigments and the relation of these to the melanins derived from tyrosine; the syntheses of tryptophan and nicotinic acid; and interrelations with the pterins, riboflavin, and uric acid—alike offer new biochemical perspectives. Although Tanaka's review often takes on the form of a catalog and makes dull reading, it is impressive in more than one respect. Perhaps the most significant fact is the answer provided those who raise the question, no doubt because of acquaintance only with the genetics of *Drosophila*, whether morphological mutations ever affect larval or other immature stages. Tanaka describes 22 egg characters, no less than 100 larval characters, 12 cocoon characters, and 8 pupal characters. Here is at least one animal which presents more immature than imaginal genetic differences. Or is it merely that the geneticist's attention is fixed in the case of *Drosophila* on the imago and in the case of *Bombyx* on the silkworm? At any event, never again will anyone be able to claim that mutations affect only the mature stages of the life cycle.

BENTLEY GLASS

ADVANCES IN GENETICS. *Volume VI.*

Edited by M. Demerec; editorial board, G. W. Beadle, William C. Boyd, Th. Dobzhansky, L. C. Dunn, Merle T. Jenkins, Jay L. Lush, Alfred Mirsky, J. T. Patterson, M. M. Rhoades, L. J. Stadler, and Curt Stern. Academic Press, New York. $9.80. x + 488 pp.; ill. 1954.

This volume sustains the high quality of scientific and editorial excellence of the preceding volumes. The eight contributions deal with topics of theoretical and practical significance in the genetics of micro-organisms, insects, cattle, plants, and man.

In Map Construction in *Neurospora crassa*, Raymond W. Barratt, Dorothy Newmeyer, David D. Perkins, and Laura Garnjobst have drawn upon all the available data and have devised a new mapping function from a 4-strand model of crossing over in order to construct maps of the seven linkage groups, containing a total of 75 loci, in *Neurospora*. In Genetic Changes in Human Populations, Especially Those Due to Gene Flow and Genetic Drift, Bentley Glass has reviewed many of the recent results of studies on human populations which yield quantitative estimates of the rate of gene flow and of genetic drift. These descriptive quantities, along with measures of mutation rates and selection pressures, will substantially advance the science of human population genetics.

In Monozygotic Twins in Cattle, John Hancock has summarized the data on the occurrence of twinning, the hypotheses which may explain twinning, and the numerous criteria for monozygotic twins. In addition, the uses of twins in experimentation and in heritability studies are discussed. The Genetics of the Newer Human Blood Factors, by Philip Levine, reviews the genetic status of the nine better known human blood factors and the applications of this information in medical practice and in human population genetics.

In Comparative Incompatibility in Angiosperms and Fungi, D. Lewis has analyzed the genetic basis of incompatibility and has briefly discussed the applications of incompatibility in plant breeding. Cytoplasmic Inheritance in *Epilobium* and its Theoretical Significance, by P. Michaelis, brings up to date the extensive researches by the author on this phenomenon, at the same time pointing out numerous gaps in our knowledge of the role played by the cytoplasm in development. The Genetics of *Colias* (Lepidoptera), by Charles L. Remington, is a thorough summary of the named genes in the various species of *Colias*, with special emphasis on the sexual polymorphism common in these species. In the final contribution, on Artificial Insemination and Livestock Improvement, Alan Robertson discusses the growing role of artificial insemination in animal breeding throughout the world.

E. L. GREEN

POPULATION GENETICS.

By Ching Chun Li. The University of Chicago Press, Chicago. $10.00. xii + 366 pp.; ill. 1955.

This volume is based on the author's earlier book, published in 1948 at Peiping. Much has been rewritten, some new material has been added, and one chapter on segregation in small families (which is not really a part of population genetics) has been omitted. The largest increase is in the notes and exercises at the ends of the chapters.

This is appropriate either as a textbook for the beginning student in population genetics or as a reference for those in the field. It deals almost exclusively with population genetics (as opposed to biometrical genetics), and with the mathematical theory rather than with experimental work. By restricting his field the author has been able to treat the subject more completely than it is in any other book I know of, and in considerable detail. The presentation is sometimes original, but more often similar to that of the original author (usually Fisher, Haldane, or especially, Wright). The unique characteristic of the book is the care that the author has taken to make the mathematics entirely clear. Often he does this by writing out in full algebraic steps that are omitted in the original publications. An-

other feature of the book is a full treatment of path coefficients. Here again the manner of derivation and application are almost a paraphrase of Wright's original papers, but the material is presented so fully and coherently as to be easily followed by anyone willing to take the trouble to read it carefully.

The book is always clear, and the material is presented in the most elementary way possible. The reader needs only a knowledge of formal genetics, algebra, and elementary calculus; whenever any more advanced material is used it is explained at that time. I think students will welcome the numerical examples and the large section on notes and problems, which contain important material, not merely contrived exercises.

The concepts of genetic variance and correlation between relatives are introduced early and are used throughout the book. The first few chapters are devoted to the formal genetics of a single locus in a randomly mating population, with consideration of multiple alleles, sex-linked genes, autopolyploids, and self-sterility factors. Then there is extension to more than one locus and to various simple inbreeding systems. Following this is a section on path coefficients and their application to inbreeding and heterozygosis. Finally are several chapters on the effects of mutation, selection, and migration in natural populations and the stationary distribution of gene frequencies in finite populations.

It is inevitable that a book written in such a way as to be understandable to the beginner with limited mathematical knowledge is lacking in mathematical elegance and generality. The mathematically more sophisticated studies of Feller, Malécot, and Kimura are omitted, in my opinion wisely, for this treatise was not written for those already well acquainted with population genetics theory. I think the book fills its intended purpose extremely well.

The book is very well printed and the new format and additional diagrams are a big improvement over the original edition. My major objection is to the price; ten dollars seems a lot to ask.

JAMES F. CROW

PRÉCIS DE PHYTOGÉNÉTIQUE.

By G. Kuhnholtz-Lordat; Preface by Pierre-P. Grassé. Masson & Cie, Paris. 2000 fr. (paper). xii + 390 pp.; ill. 1952.

This book, intended as a textbook for students in genetics as related to agriculture, has a very different approach from that adopted in textbooks in the English language. As stated in the Preface, the order of topics is intended to progress from the more simple to the more complex phenomena, and therefore "from the stigma to the gene." The weakness of this arrangement is that the explanation of the phenomena mentioned in the early chapters is not at all apparent to the student, since the basic principles upon which the explanations rest, viz., the Mendelian laws and chromosomal behavior, are not introduced until the latter half of the book. In taking up these principles of genetics, the author adopts an unusual and confusing sequence. Instead of discussing the different types of crosses (monohybrid, dihybrid, etc.) as separate units, he has included all types of F_1 hybrids in one section and all types of F_2 segregation with independent assortment in the next. Linkage, however, is left to a much later section, and appears after the discussion of crossing over, chromosome rearrangements, and position effects. As a teacher of beginning genetics, I have difficulty in seeing how such an arrangement could provide the student with any idea of the logical sequence of cause and effect, or prediction and experimental verification, which is the very essence and beauty of modern basic genetics. The book appears more like a sequence of short descriptions and definitions of terms, which are intended to be memorized, than a logical and well organized discussion.

As a modern text, the book has some grave omissions. Biochemical genetics is almost completely ignored, in spite of the important work in this field being done in France. Among the several hundred names of modern scientists listed in the index, one looks in vain for that of Boris Ephrussi, considered by many to be the leading French geneticist who has worked with plant material; his former co-worker G. W. Beadle is also omitted. Although intended for agricultural students, the book refers only cursorily to the statistical basis of plant breeding, while such important phases of population genetics as the relation between artificial and natural selection, and the ecotype concept, are completely ignored. It is hard to see how a book could present a complete picture of modern plant genetics without referring to the work of E. M. East, O. Winge, G. Turesson, J. Clausen or R. E. Clausen, O. Renner, H. Kihara, K. Mather, or A. Gustafsson, none of whom are mentioned.

The American reader will find little to interest him in this book, except perhaps for a few unfamiliar examples of plant breeding, such as selection for increased oil content in the palm, *Elaeis guineensis*. If the book is truly representative of the teaching of genetics and plant breeding in France, one cannot escape the conclusion that this branch of biology is far more poorly developed there than in most other western countries.

G. LEDYARD STEBBINS

AN INTRODUCTION TO HUMAN BIOCHEMICAL GENETICS. *Eugenics Laboratory Memoirs, XXXVII.*

By H. Harris; with a Foreword by L. S. Penrose. Published for The Galton Laboratory, University College,

London, by the Cambridge University Press, New York and London. $2.75 (paper). ii + 96 pp. + 4 pl.; text ill. 1953.

The study of human inborn biochemical variations stems from the work on alkaptonuria by A. E. Garrod, whose portrait fittingly serves as frontispiece for this publication, and from Karl Landsteiner's discovery of the ABO blood groups in the preceding year. In the past fifteen years both the known "inborn errors of metabolism" and the more normal biochemical variations have greatly increased in number. There is consequently a great need just now for a clear and comprehensive discussion of human biochemical genetics. The treatment of the subject by H. Harris, who is himself very active in this field, most satisfactorily fills that need. Each category of condition is treated with sufficient fullness and by a great enough variety of examples to give the reader a real grasp of the matter, yet without that superfluity of detail and that infinitesimal cataloguing of every variation which render so many medical and scientific treatises hard to digest.

After appropriate introductory chapters on the nature of Inborn Biochemical Variation, and Mendelian Heredity in Man, Harris deals successively with The Heterogeneity of Apparently "Simple" Characters, such as cystinuria, methemoglobinemia, alkaptonuria, and the A_1 and A_2 blood groups; with Blocks in Intermediary Metabolism, such as those in phenylketonuria, alkaptonuria, tryosinosis, fructosuria, and glycogen disease; and with Variations in Renal Tubular Function, especially in glycosuria, cystinuria, and β-amino*iso*butyricaciduria. A very clear discussion of the varieties of hemoglobin and of the blood group substances and the secretor trait is followed by a chapter on the differences in capacity to taste the thioureas. Lastly, variation in the manifestation of hereditary characters is considered, the relation of gout to hyperuricemia and to sex providing a particularly fine example.

This monograph is not exhaustive, and the advance of knowledge in the field will soon render it even more incomplete. Yet it may long continue to serve as an introduction to the subject, which is destined to become increasingly significant in medicine, in genetics, and in biochemistry. It will remain of use because of the exemplary clarity and balance in treatment it achieves and because of its attention to principle. The reader cannot fail to be intrigued by the great variety of interesting problems obviously awaiting solution in the study of human biochemical genetics.

BENTLEY GLASS

HEREDITY IN HEALTH AND MENTAL DISORDER. *Principles of Psychiatric Genetics in the Light of Comparative Twin Studies.*

By Franz J. Kallmann; with a foreword by Nolan D. C. Lewis. W. W. Norton & Company, New York. $6.00. 315 pp.; ill. 1953.

For many years the author of this book has had an interest in psychiatric genetics. He has added to our knowledge about the genic conditioning of psychoneurotic and psychotic traits. Also he has endeavored by suggestion and example to promote professional cooperation among the specialists working in the various fields of the problem. This same interest was the basis of the author's lectures presented in the nineteenth series of the Thomas W. Salmon Lectures. Now he has organized the subject matter into book form for wider usage.

The subject matter is presented under three main headings: Part I, Heredity in Relation to Mental Health; Part II, Heredity in Relation to Mental Disorder; and Part III, Contributions of Genetics to Mental Health Planning. The author has reviewed and summarized the data on psychiatric genetics which have been reported by European and American investigators. He has made extensive use of information that he and his collaborators have collected in studies of twins and their relatives. A good choice has been made of graphic and tabular means for presenting the data. The author has illustrated his interpretations of the data by using a large number of photographs of monozygous and dizygous twin pairs, with some of them shown in age seriation.

Part I includes a brief résumé of the development of genetics and of psychiatry to the level of modern science. The general principles of genetics are presented very briefly. A discussion of the methods used in studying human genetics is not extensive, but the coverage is broad enough for the purposes of the book.

A series of photographs and tabular material are used to show that monozygous twins have high concordance and dizygous twins lower concordance for physical and medical characteristics which are generally considered hereditary. Concordance among these twins for intellectual performance and adjustive capacities closely parallels the patterns for physical traits.

In Part II, the author calls attention to the paucity of our knowledge about the part genes play in minor psychoneurotic deviations. Individuals vary in the difficulties they have adjusting to circumstances. Each personality has its own threshold of resistance to stress type. For obvious reasons the mechanism of inheritance for these deviations is not well known. Concordance of twin-pairs can be used to measure the relative effects of heredity and environment. The data collected by the author indicate that suicidal tendency can be no more than weakly hereditary; discordance is very high for both kinds of twins. On the other hand, a high concordance rate of monozygous twins in contrast to the low concordance for dizygous twins gives evidence that there is a strong hereditary tendency for the deviation resulting in homosexuality.

Psychotic reaction types lend themselves more readily to genetic analysis. A considerable portion of this part of the book is given to discussions of the significance of genetic phenomena in common psychiatric disorders. Carriers of a particular genotype have a biological capacity for reacting to precipitating environmental stimuli with a specific type of psychoses. The data show that an individual's tendency to develop schizophrenia, manic depressive psychoses, or involutional psychoses depends upon the particular type of psychoses in his relatives. Families with a history of manic depressive psychoses have members who are schizophrenic no more often than one would expect on the basis of population frequencies. Schizophrenia and involutional psychoses occur in the same family group more often than would be expected by chance.

A hereditary basis for the tendency to develop a psychotic disorder is evidenced by the high frequency of occurrence of the disease in close relatives as compared to non-relatives of an affected person. The frequency decreases with each step down in degree of relationship from the patient, with monozygous twins most likely to be alike. The author does not ignore possible effects of environmental factors. He recognizes that methods used in studies may sometimes result in erroneous interpretations unless caution is used. For example, the high concordance (100 per cent) among monozygous co-twins for manic depressive psychoses may be explained by the fact that one was used as a proband only if he required hospitalization. Mild cyclic cases would less likely be included in the study.

Schizophrenia is interpreted as due to a recessive pair of primary genes with secondary or modifying genes affecting the phenotypic expression. Morbidity rates for relatives of schizophrenic patients are therefore lower than those reported for relatives of patients having the dominant manic depressive psychoses. In each instance, however, the morbidity rates among relatives parallel the degree of consanguinity to a patient. Both schizophrenic and manic depressive patients are reported to have higher celibacy rates and lower reproductive rates among the married individuals that those rates found for a comparable general population group. The author suggests that schizophrenics who have children are likely to be those with relatively mild symptoms.

A number of uncommon neurological defects are recognized to be strongly hereditary. For some of them the mechanism of inheritance has been established. For others, the hereditary basis is less well known but familial tendencies are strong and the rate of concordance is high for monozygous in comparison to dizygous twins. Among the traits discussed in the book are epilepsy, mongolism, and the various disorders associated with skin defects, skeletal defects, and defects in metabolism.

In Part III, the author makes an earnest plea for geneticists and psychiatrists to recognize the interrelationship of their problems in mental health. They have the same ultimate goal, to get an effective cure of gene-dependent mental disorders. Their immediate aim is to determine more accurately the probability that an individual will develop a mental disorder and to prevent its occurrence. Interprofessional cooperation is needed.

Attention is called to common misconceptions concerning human genetics, and an effort is made to correct these errors in thought. Some non-genetical workers believe that hereditary traits are not subject to therapy. Others are disturbed by the unfortunate uses which some people have made of genetical research to advance their particular fanaticisms.

The science of human genetics should be advanced, but geneticists must recognize that weaknesses in the science exist. Geneticists should discover which traits have a hereditary basis and then determine the mechanism of inheritance, selective pressures, and mutation rates. The author emphasizes that public health officers should have genetical training and psychotherapeutical experience in order that they can give guidance on problems of marriage, parenthood, and inheritance when guidance is sought by responsible people having adjustive problems.

The reader who may want to examine the scientific publications on the subject matter will find that an excellent bibliography is included in the book.

CLARENCE P. OLIVER

AUTORADIOGRAPHY IN BIOLOGY AND MEDICINE. *By George A. Boyd. Academic Press, New York.* $8.80. xiv + 399 pp. + 1 pl.; text ill. 1955.

This book will be of interest and value to most experimental biologists whose work involves the use of radioactive isotopes. It represents the first attempt to bring together working descriptions of the various techniques of biologically applied autoradiography and introduces them with some essential information on the nature of the photographic emulsion and its interaction with the energies emitted during radioactive decay. An extensive and very useful bibliography of the work in the general field is included.

The work serves its purpose very well: the researcher who has never done autoradiography is presented with a useful tool and enough instructions regarding its use to be able to begin its application. What is perhaps equally important, the extensive theoretical treatment and the discussion of the multitude of factors which enter into any work with photographic emulsions serve to caution the beginner against the expectation of perfect results from the mere following of the instructions given for a particular method for the first time.

It is somewhat disappointing that the book does not convey a very adequate idea of the capabilities of the technique at its upper limit, when applied to studies on the cell. Various methods in use for high resolution autoradiography are described; the photomicrographs presented, however, are not likely to convince the critical reader that the theoretical degree of resolution has been attained, particularly since the magnifications used are not given.

On the whole, the book successfully fills a gap in the literature on modern analytical techniques. The fact that the author has, generally, restricted himself to the discussion of well-established principles should help in maintaining the book's usefulness as an introduction in the face of the rapid development of some aspects of the technique.

W. PLAUT

ANALYTICAL CYTOLOGY. *Methods for Studying Cellular Form and Function.*

Edited by Robert C. Mellors; foreword by Francis O. Schmitt. The Blakiston Division, McGraw-Hill Book Company, New York, Toronto, and London. $15.00. xii + 486 + 30 pp.; ill. 1955.

Professor Schrader, in his 1948 appraisal of the status of cytology (*Science*, 107: 155–159), predicted that the year 1950 would mark the end of a quarter-century period dominated largely by cytogeneticists and would inaugurate a new era in which the leading roles would be played by the biochemists and biophysicists. How closely this prediction will approach reality must, of course, await the passing of many more years. Certainly the remarkable progress made in microbial and viral genetics, and the far-reaching significance of position pseudoallelism and other position-effect phenomena in Drosophila and maize, indicate that the geneticist and cytologist will still have a word to contribute to the future analysis of the fine structure of the cell and its hereditary and developmental roles; but the publication of this volume, with its extensive bibliography, is indicative of other directions in which cytology has been moving. The present pace of research is also indicative of a gaining momentum which is not likely to slacken soon.

Analytical cytology is defined in the Foreword by F. O. Schmitt as a synthesis of cell morphology and biochemistry. As such, the term is not particularly appropriate, for there are many other aspects of cytology which are equally analytical, and the connotations are not as sharply defined as for such terms as cytogenetics or cytochemistry. Be that as it may, analytical cytology is in what might be called the pilot-plant stage of development, for the tools and methods, with which this volume is largely concerned, have not yet become subordinate to the real goal of understanding the cell in all of its functions and structures. This is, of course, understandable and natural, for the limitations of tools and methods must be thoroughly understood and the techniques must be mastered before confidence in their use can be gained.

Under the editorship of Professor Mellors, the volume is divided into two sections, the first of which deals with methods employing the optical spectral region, while the second discusses methods making use of electrons, radioactive isotopes, and x-rays. In an unusual arrangement, each of the 9 papers is separately paginated. In the first section, the problems of cytophotometric analysis are discussed by Pollister and Ornstein, while staining methods are handled by Novikoff. Barer deals with phase-contrast, interference-contrast, and polarizing microscopy, Nurnberger with ultraviolet microscopy and microspectroscopy, and Richards with fluorescence microscopy. In the second section Selby discusses electron microscopy, Fitzgerald radioautography, Engström historadiography, and Oster x-ray diffraction techniques as applied to the study of biomolecular structures. With the exception of Novikoff's article, the emphasis is therefore on the physical aspects of radiation as tools for revealing the structure and localization of biochemical differences within the cell. Each chapter is fully documented, and while differences of interpretation and emphasis will certainly be voiced by others equally immersed in the several specialized fields, the compilation of these techniques within one set of covers makes the volume itself an indispensable research tool. There can be little doubt that the development of the tools and methods described has reawakened an intense interest in the cell, but it will take another historian of cytology in 1975 or 2000 to see the results in their proper perspective, and to render a fair and just appraisal.

C. P. SWANSON

ABSTRACT BIBLIOGRAPHY OF COTTON BREEDING AND GENETICS, 1900–1950. *Technical Communication 17 of the Commonwealth Bureau of Plant Breeding and Genetics.*

By R. L. Knight. Commonwealth Agricultural Bureaux, Franham Royal, England. 21s. vi + 256 pp. No date.

The list of publications dealing with cotton breeding and genetics numbers 1191, and Knight has abstracted each one in sufficient detail to convey its essential contents. A considerable number of Russian publications is included. The abstracts are arranged alphabetically by author, and an index permits ready cross referencing in terms of subject matter. A brief appendix lists the genomes of *Gossypium*, while a longer one treats the known genes in terms of symbolic representa-

tion, genetic effect, reference source, and species in which found. Anyone interested in the genetic aspects of *Gossypium* should find this compact volume an invaluable reference.

C. P. SWANSON

GENERAL AND SYSTEMATIC BOTANY

TREES AND SHRUBS OF THE UPPER MIDWEST. *By Carl Otto Rosendahl. University of Minnesota Press, Minneapolis.* $6.00. viii + 411 pp.; ill. 1955.

VASCULAR PLANTS OF ILLINOIS. *Museum Scientific Series, Vol. VI.*

By George Neville Jones and George Damon Fuller; prepared with the collaboration of Glen S. Winterringer, Harry E. Ahles, and Alice A. Flynn. The University of Illinois Press, Urbana; Illinois State Museum, Springfield. $10.00. xii + 593 pp.; ill. 1955.

Both of these volumes are done by men who have spent the greater part of their professional lives in the areas which they describe, and who know in a botanical way the upper portions of the Midwest as few can know it. The books are therefore the distillations of many years of experience; this is quite evident in the thoroughness with which each of these two volumes has been prepared. The differences in aims have, however, led to two quite different books.

Professor Rosendahl's volume covers an area which includes Minnesota, Wisconsin, parts of Iowa, and N. and S. Dakota east of the Missouri River. The intended audience includes the nature lover, the gardener and the amateur as well as professional botanist. Numerous illustrations are used as aids in the recognition of members of the woody vegetation, a useful key permits ready identification of any unfamiliar species, and a glossary acquaints the reader with the meaning of the terminology employed. The volume is artistically done, and in so far as any taxonomic work can be unambiguous, this one is. It is a work which should be extremely useful to a wide variety of plant lovers at the same time that it will be an asset to the professional botanist. Rosendahl is to be complimented for his splendid addition to the botanical literature.

The book by Jones and Fuller restricts its geographical coverage to the State of Illinois, but in doing so extends its descriptions to include all of the vascular plants rather than just the woody species. It differs further from the above volume in that it is a taxonomic compendium written for the professional taxonomist. The general plan of the work is to cover each species in the state with the current valid binomial, the authority, with place and date of publication, and a list of all known references to the occurrence of the species within the state. A brief description of habitat is given, as is the common name. No illustrations or taxonomic descriptions are supplied. Maps accompany most species to indicate collecting sites.

Even a cursory examination of these volumes indicates the wealth of plant material which exists in the upper central Midwest, and the two volumes in a sense complement each other although they do not overlap geographically. They provide an excellent coverage of a rich and interesting region of the United States.

C. P. SWANSON

PLANT PHYSIOLOGY

ANNUAL REVIEW OF PLANT PHYSIOLOGY. *Volume 6. Edited by Daniel I. Arnon; associate editor, Leonard Machlis. Annual Reviews, Stanford.* $7.50. xii + 505 pp.; ill. 1955.

The sixth volume of the *Annual Review of Plant Physiology* maintains its usual high level of review writing—interpretive and coherent, rather than a mere listing of a scattered bibliography. This is the last volume to be edited by D. I. Arnon, and he has taken this occasion to include a short statement on the aims and accomplishments of the *Annual Review of Plant Physiology* to date. To me, as to most plant physiologists, it would seem that the series has indeed done valuable service in its attempt to "provide integration and encourage synthesis in the broad field of plant physiology." Arnon and his associates, as well as the contributors to the series, deserve a great deal of praise for the successful establishment of these Annual Reviews. In the long run, their contribution is just as significant as any experimental accomplishment.

This volume is distinguished by three articles overlapping the field of plant pathology: Pathogenesis in the Wilt Diseases, by A. E. Dimond; Chemical Nature of Disease Resistance in Plants, by J. C. Walker and M. A. Stahmann; and Adaptation of Plant Pathogen to Host, by J. J. Christensen and J. E. DeVay. These articles illustrate the flexible editorial policy established in the *Annual Review of Plant Physiology*, in that the same titles have not appeared in any previous volume, and that the topics covered are distinctly on the borders of other disciplines. Some of the concepts in this particular area appear to have reached a remarkably advanced and specific state, and should be of especial interest to physiologists who do not spend much or even any time on phytopathological literature.

The article on The Nutrition of Plant Tissue Cultures, by R. J. Gautheret, outlines the enormous size and complex nature of the field of the organic nutrition of plants. Progress in this area is scattered at present, and the next few years could easily see the isolation of many compounds from natural sources that promote or inhibit the growth of tissue cultures, at present known only as "factors" present in a mixture.

The enormous chemical synthetic abilities of plants are represented in two articles by distinguished workers in their respective fields: Physiology of the Alkaloids, by K. Mothes; and Colour Development in Flowers, by Karl Paech. Water physiology, after a lapse of four years, is discussed in two articles: The Water Economy and Hydrature of Plants (H. Walter), and Water Relations of Plant Cells and Tissues (P. J. Kramer).

Chemical Constitution as Related To Growth Regulator Action is discussed by R. M. Muir and C. Hansch. This article has relatively little in it on the mechanism of the physiological effects of auxin; however, considerable amounts of auxin literature are included in The Physiology of Flowering, by J. L. Liverman.

The article on Nitrogen Metabolism (G. C. Webster) includes a large amount of material on the biochemical pathways for the transformation of nitrogenous compounds—amino acids, amides, peptides and proteins. Also concerned with details of metabolism is Biochemical Aspects of Photosynthesis (W. Vishniac).

Other articles in this volume cover Mechanism of Absorption, Transport, Accumulation and Secretion of Ions (H. Lundegardh); Redistribution of Mineral Elements during Development (K. F. Williams); Functional Aspects in Mineral Nutrition of Green Plants (A. Pirson); Effects of Ecological Factors on Photosynthesis (M. D. Thomas); and Physiology of the Cotton Plant (F. M. Eaton).

A. T. JAGENDORF

ECONOMIC BOTANY

VEGETABLE TANNING MATERIALS.

By F. N. Howes. The Chronica Botanica Company, Waltham; Butterworths Scientific Publications, London. $5.50. xii + 326 pp.; ill. 1953.

Tanning has its origin in our prehistoric past, when man first found, probably accidentally, that certain vegetable materials aided in the preparation of skins for clothing. Vegetable sources continue to supply the majority of tannins currently in use, although synthetic products, particularly the chromes, have been extensively employed for certain types of leather. The extent to which vegetable tannins enter into the leather industry is indicated by the fact that the United States imports, in crude form, approximately 300,000 pounds per annum. There is, fortunately, more than a single source of vegetable tannins in the plant kingdom; regionally, however, the prevalence of commercially important tannin-containing species is in the tropics or semi-tropics. These include the wattles, mangroves, quebracho of South America, and mimosa, among a host of lesser species, and these in turn are supplemented by temperate zone species such as the chestnut, the oak, and the many species of gymnosperms. The bark tannins are the most important because of their ease of extraction, availability, and supply, but all plant parts contain tannin to a greater or lesser degree. Plant galls, in particular, have a high concentration, yielding up to 40–50% of their dry weight as extractable tanning material. The usefulness of any particular tannin, however, will determine the feasibility of extracting it from any specific species or its parts.

This volume, following an introductory historical account, deals with the sources of tannin, the sections being delineated on the basis of barks, woods, fruits, leaves, roots, and galls. A wealth of information is contained in this slender book, and quite apart from its usefulness to the tanning industry, it is an important contribution to general economic botany. It emphasizes implicitly the interdependence of all countries on the limited resources of the world, the possibilities of their loss, as in the case of the American Chestnut, and the need for conservation. A fine book and an interesting one.

C. P. SWANSON

THE BACTERIAL WILT CAUSED BY *PSEUDOMONAS SOLANACEARUM. A Literature Review and Bibliography. Tech. Bull. No. 99, June 1953.*

By Arthur Kelman. North Carolina Agricultural Experiment Station, Raleigh. Free upon request (paper). 194 pp.; ill. 1953.

This technical bulletin covers the history, biology, economic importance and control of one of the most destructive diseases known among solanaceous plants. The treatment is exhaustive, and an extensive world-wide list of citations permits the easy exploration of any phase of the disease in detail.

GENERAL AND SYSTEMATIC ZOOLOGY

STUDIES OF ARCTIC FORAMINIFERA. *Charles D. and Mary Vaux Walcott Research Fund. Smithson. misc. Coll., Vol. 121, No. 7. Publ. 4105.*

By Alfred R. Loeblich, Jr. and Helen Tappan. Smithsonian Institution, Washington. $2.00 (paper). iv + 150 pp. + 24 pl.; text ill. 1953.

This systematic study describes 110 species of Arctic and sub-Arctic Foraminifera, representing 20 families and 56 genera, of which 6 genera and 21 species are new, and 1 new specific name is proposed as a homonym. Many previously described species have been reassigned to other than the original genera. The source of the fauna is the Point Barrow region of northern Alaska. The original intention of the authors was to make an ecological study, but it was found that previous work on Arctic foraminiferans was so unsatisfactory that first a taxonomic study had to be made in order to straighten

out some of the tangles left by other workers. This is, however, not a monographic treatment, which is left for the future.

AUS DEM SPINNENLEBEN WÄRMERER LÄNDER. *Die Neue Brehm-Bücherei, Heft 138.*

By Hermann Wiehle. A. Ziemsen Verlag, Wittenberg Lutherstadt. DM 3.75 (paper). 87 pp.; ill. 1955.

In this popular booklet, published in the Russian Zone of Germany, Hermann Wiehle, one of the foremost European arachnologists, describes spider curiosities from other countries. The publication is abundantly illustrated and has a bibliography.

HERBERT W. LEVI

AN INTRODUCTION TO THE STUDY OF INSECTS.

By Donald J. Borror and Dwight M. DeLong. Rinehart and Company, New York. $9.00. x + 1030 pp.; ill. 1954.

One immediately notices two things about this book. First, it is much like Comstock's *Introduction to the Study of Entomology*, which has been the standard American textbook for many years and which was last revised in 1947; and secondly, its illustrations are well selected and excellently reproduced. They are a decided improvement over those in Comstock.

It is true that there is need for a new and better introduction to entomology, for a text that will impress the beginning student with the idea that there are many and diverse forms of insect life in the world, a few of which live in the United States; but it is not evident that another volume along the lines of Comstock is called for. American entomology has, for more than a century, been too provincial in character and scope, and the place to attack this tendency is in the beginner. Our native insect enemies are fairly well identified; our new pests come to us from other parts of the world.

The best feature of the book is its illustrations. The keys, too, are sufficiently rewritten to be considered original, and in general they are improvements over others that are available. The general information in the latter part of the book will be helpful; but the reviewer doubts the desirability of including in a volume that costs as much as this one does, information of interest only to boy scouts and primary school teachers.

EDWARD A. CHAPIN

INSECTS CLOSE UP. *A Pictorial Guide for the Photographer and Collector.*

By Edward S. Ross. Published for the California Academy of Sciences by The University of California Press, Berkeley and Los Angeles. $1.50 (paper). 80 pp.; ill. 1953.

Few "Guides" such as this offer a tenth as much for the price. The author is Curator of Entomology at the California Academy of Sciences and also a photographer, as his work shows, of rare skill. The numerous black-and-white and color photographs, often two to a page, are exceedingly well reproduced and are accompanied by a text written for the layman but so excellent in style and so full of startling facts about insects that any ordinary biologist, and even the professional entomologist, will find it worth reading. The book contains a section on methods for the amateur insect collector which should imbue him with the right scientific spirit; and an all too brief section on photographic methods is also included. But above all, this is a book of pictures. The close-up views of insects, taken with a sharpness and an understanding of their typical attitudes and habits altogether too rare on the part of most nature photographers, make this addition to the naturalist's library a real prize. If it becomes as widely known as it should, it will undoubtedly fulfil the author's intention, which is to persuade amateur hobbyists to become real scientists in their spare-time activities.

BENTLEY GLASS

A REVISION OF THE BEE GENUS *COLLETES* IN AMERICA NORTH OF MEXICO (HYMENOPTERA COLLETIDAE). *Univ. Kans. Sci. Bull., Vol. XXXVI, Pt. I, No. 6, June 1, 1954.*

By W. P. Stephen. The University of Kansas Press, Lawrence. Free upon request (paper). Pp. 149–527; ill. 1954.

This excellent taxonomic revision of the North American species of a difficult genus of solitary bees is of primary interest to the taxonomist. The North American fauna contains over a hundred species, but surprisingly little is known of the bionomics of more than a few species. The author includes brief statements on the biology, distribution, and phylogeny, before beginning the taxonomic section. The component species are divided into 19 species groups based primarily on characters of the male genitalia, antennae, clypeus, punctation, and others. Some of these groups occur throughout the Holarctic Region, while a few others occur also in the Neotropical Region.

Separate keys are presented for the two sexes. The treatment for each species consists of the synonymy, complete except for catalog citations, detailed descriptions of each sex, and records of distribution, flight period, and plants visited. The seventh ventral plate

and details of the genitalia are figured for all males. The distribution of some of the species and subspecies is illustrated by 8 maps.

KARL V. KROMBEIN

A MONOGRAPHIC REVISION OF THE ANT GENUS *LASIUS*. *Bull. Mus. comp. Zool. Harv., Vol. 113, No. 1.*

By Edward O. Wilson. Museum of Comparative Zoology, Harvard College, Cambridge. $1.85 (paper). 199 + ii pp. + 2 pl.; text ill. 1955.

These are—to me—the least interesting of all ants. They are indifferent in size and color; their morphological monotony is relieved by few specializations; there is little or no remarkable behavior; their direct economic importance is slight. Nevertheless they must be reckoned with, for throughout its range (the temperate parts of the Holarctic) *Lasius* is among the most abundant of all insect genera.

If the ants themselves are uninteresting, not so this monograph, which comprises a section on phylogeny within the genus and one on the species and subspecies concept; a glossary of terms; ten pages of keys; and the Systematic Treatment by Species. In this last the plan is: synonymy, diagnosis, description of type, further description, geographic variation, distribution, ecology. Considerable biometry is incorporated, and infraspecific variation is considered at some length.

Two noteworthy features distinguish this monograph. First, it is based on a massive amount of material —"an estimated total of 5,425 nest series containing approximately 80,000 specimens." This is "the largest amount of material ever assembled for a revision of any group of ants, and one excelled by few other collections of special insect groups."

The second feature is truly revolutionary: the abandonment of the subspecies. When I began studying myrmecology in the early 'twenties, we had pentanomial nomenclature: genus, subgenus, species, subspecies, variety. The variety was given the coup de grâce by Creighton in 1950, but the subspecies will be more resistant. Personally I favor the attendant simplification of nomenclature, but there will certainly be opposition from other taxonomists. Wilson has reduced "the 110 unchallenged names which existed in the literature at the outset of this revision" to "only 27 as representing valid species (not counting the six additional new species)".

Now that *Lasius* has been set in order, the next myrmecological stable to be cleaned is the closely related genus *Formica*. I supplied Wilson with 1,000 of his 5,400 series of *Lasius*, but I have 1,500 series of *Formica*. Are there any volunteers?

GEORGE C. WHEELER

MEMORIE DI BIOGEOGRAFIA ADRIATICA. *Volume II. Published with the support of the Consiglio Nazionale delle Richerche.*

By Umberto d'Ancona. Istituto di Studi Adriatici, Venezia. Paper. iv + 286 pp. + 1 folded map; text ill. 1953.

A collection of 9 zoological papers written in Italian, German, or French, and provided with summaries in English and Italian. The subjects are as follows: Some characteristics of the Apulian mammalian fauna (A. Pasa); Ants from Apulia and the Tremiti Islands (M. Consani); Cave Collembola of Apulia with the description of a new Italian species of the gen. *Troglopedetes* Absolon (C. Delamarre-Debouteville); A collection of bees from Apulia (B. Pittioni); Cave Arachnida of Apulia (L. di Caporiacco); On the cave pseudoscorpions described by L. di Caporiacco from Apulia (M. Beier); The terrestrial isopodologic fauna of Apulia and the Tremiti Islands and its probable origin in relation to the diffusion of transadriatic species (A. Arcangeli); Some geological notes on the palaeogeography of the Puglie (A. Pasa).

IMMATURE STAGES OF INDIAN LEPIDOPTERA. *No. 8, Geometridae. Indian For. Rec., N. S., Entom., Vol. 8, No. 7.*

By Balwant Singh. Manager of Publications, Delhi. Rs. 4/8/- or 7s. (paper). iv + pp. 67–158 + 10 pl. 1953.

A taxonomic study of the larval characters of 62 species and a few unnamed forms belonging to 46 genera of the Geometridae, with keys to subfamilies, genera, and species.

FISHES OF THE WESTERN NORTH ATLANTIC. *Part Two, Sawfishes, Guitarfishes, Skates and Rays; Chimaeroids. Memoir Sears Fdn. mar. Res., No. 1.*

By Henry B. Bigelow and William C. Schroeder. Sears Foundation for Marine Research, Yale University, New Haven. $15.00. xvi + 588 pp.; ill. 1953.

The declared objective of the editorial board for *Fishes of the Western North Atlantic* is to "... bring together in a uniform series of volumes a complete account of the fish fauna of this region...." Part One, on Lancelets, Cyclostomes and Sharks, 1948 (*Q. R. B.*, 24: 365. 1949), and the present volume certainly accomplish this objective, for the chondrosteans, with a degree of excellence that can bring only praise to its authors.

This memoir is written for "those in many walks of life," including fishermen, sportsmen, amateur ichthyologists, professional scientists, and "those

casually or vitally interested in the general phenomena of life in our waters." The non-technical style in arrangement of descriptive material, simple keys, and clear, easily read text should be welcomed by all, laymen or scientists. The careful, explicit handling of data and qualified generalizations or expressions of opinion keep the reader informed regarding the exact status of the facts being presented.

In preparing this comprehensive review the authors have not merely compiled information from the literature but have reexamined available specimens in the extensive collections of the Museum of Comparative Zoology at Harvard, the United States National Museum, and other museums. While the book was being written a great deal of exploratory fishing was in progress, particularly by the M/V "Oregon" in the Gulf of Mexico, by the "Atlantis" in the West Indies, and by commercial fishermen and others off the Middle Atlantic and New England coasts of the United States. No fewer than 14 new species of skates and one new chimaera were collected, and these, described by the authors in other publications, are included here. The skate fauna of the West Indies and Gulf of Mexico formerly was considered rather poor in number of species, but trawling in depths of 50 to 400 fathoms has disclosed a surprising variety which have required 3 additional genera and 1 additional family (also previously described separately).

The discussions under the larger categories of family and genus include information on the biology, distribution, and taxonomy on a world-wide basis. The keys to genera, and in most groups the species keys, also include all known forms, even those living outside the western Atlantic region. Thus the scope of the volume is greatly extended. Full descriptive coverage, including sections on the size, development, relation to man, abundance, and range, along with an extensive bibliography, have been given for a total of 66 species occurring in the area. Each description of these resident species is accompanied by a clear drawing of dorsal and ventral aspects of the entire animal, plus numerous drawings of details of external characteristics (mouth, nostrils, fins, teeth, etc.) that explain the text and facilitate identification.

As in Part One of the series, this edition is limited to 2500 copies printed on 50 per cent rag text paper. Pages are 9 × 12 inches with wide margins.

LOREN P. WOODS

FISKARNA I FÄRG. *Second Edition.*

By Kai Curry-Lindahl; ill. by N. Norvil. Almqvist & Wiksell, Stockholm. S.Kr. 11.00 (cloth); 8.75 (paper). viii + 183 pp.; ill. 1953.

The text of this book is in Swedish, and although simply written, its usefulness is thereby restricted in this country to the relatively few who can handle the Scandinavian tongue. However, the 64 plates, done in watercolor, and including several hundred species, are superb, and make this paper-backed volume well worth its modest price. Common as well as scientific names identify each species, and the descriptions cover identifying features, range, season, food preferences, abundance, and economic importance.

C. P. SWANSON

FISHES OF JAPAN. *Illustrations and Descriptions of the Fishes of Japan.*

By Yaichiro Okada. Maruzen Company, Tokyo. $10.00. 434 + 28 pp.; ill. 1955.

In a style that is common in Japanese natural history books this treatise describes only the species that are illustrated, but it so treats 391 species—about one-third of the large total of known Japanese fishes. These are well selected to include the commoner and more frequently encountered fishes of the island empire. The 391 illustrations, partly copied and partly original, are of uniformly high quality. Under each figure is a short description of the species, followed by a more or less brief statement headed Habits, but including data on distribution, ecology, life history, and economic utilization. Much of this information is otherwise not readily available to scientists outside Japan and constitutes a definite contribution to ichthyology. The book is entirely in English and is well written and neatly printed. Errors are relatively few.

CARL L. HUBBS

THE SYSTEMATIC POSITION OF *LANTHANOTUS* AND THE AFFINITIES OF THE ANGUINOMORPHAN LIZARDS. *Bull. Amer. Mus. nat. Hist., Vol. 105, Art. 1.*

By Samuel Booker McDowell, Jr., and Charles M. Bogert. American Museum of Natural History, New York. $3.00 (paper). 142 pp. + 1 chart + 16 pl.; text ill. 1954.

This is a highly technical and competent report on the anatomy and relationships of the Bornean lizard *Lanthanotus*, of which there is only one specimen extant in museums of the Western Hemisphere. McDowell and Bogert show that this lizard is not a close relative of the Gila Monster (*Heloderma*), as had hitherto been thought, but is more closely related to two extinct families of lizards. *Lanthanotus* has many primitive features which would be expected in forms closely allied to the stock from which lizards and snakes diverged. Reasons are given for suggesting that certain kinds of worm snakes (Typhlopidae) would better be considered a family of legless lizards than a family of snakes. This report makes a very considerable con-

tribution to our knowledge of the relationships among the lizards and will be of great value in elucidating the problem of the origin of the snakes.

ARNOLD B. GROBMAN

ATTRACTING BIRDS TO YOUR BACKYARD.

By William J. Beecher. All-Pets Books, Fond du Lac. $1.00 (paper). 63 pp.; ill. 1955.

This little book provides useful tips for attracting birds in cities, suburban areas, and farther out in the country. It is not as pretentious as many other publications on the subject, but does include much of the essential information. More is given here about the behavior of birds than is usually to be found in such books. By using this background knowledge, the intelligent reader can devise some of his own methods and techniques. The illustrations were drawn by the author in his own characteristic style.

HENRI C. SEIBERT

ECONOMIC ZOOLOGY

RAT QUALITY: A CONSIDERATION OF HEREDITY, DIET AND DISEASE. *Proceedings of the Symposium held at Columbia University, College of Physicians and Surgeons, New York, January 31, 1952.*

By W. E. Heston, G. E. Jay, Jr., H. Kaunitz, H. P. Morris, J. B. Nelson, S. M. Poiley, C. A. Slanetz, Lois M. Zucker, and T. F. Zucker. The National Vitamin Foundation, New York. $2.50 (paper). ii + 138 pp.; ill. 1953.

Nine papers, presented in the symposium, are included in this publication together with the discussion that followed each formal presentation. The papers were as follows: Growth Criteria (Lois M. Zucker); The Natural History of Chronic Respiratory Disease in the Albino Rat (John B. Nelson); Development of Inbred Strains and Their Use in Research (W. E. Heston); Problems in Breeding for Quality (Theodore F. Zucker); Some Studies of Genetic and Nutrition Factors Which Influence Uniformity in Laboratory Animals (Harold P. Morris); History and Information Concerning the Rat Colonies in the Animal Section of the National Institutes of Health (S. M. Poiley); The Use of Inbred Strains in Biological Research (George E. Jay, Jr.); Evaluation of Commercial Rat Diets (Charles A. Slanetz); and Experiences with Semi-Purified Diets as Stock Rations (Hans Kaunitz). Workers concerned with the genetics, nutrition, or diseases of mammals, or any who rear and care for rats used in experimental work will do well to examine this publication. The interplay of differing points of view in the discussion is particularly illuminating.

THE WOODMONT STORY. *Hunting and Fishing and Raising Wild Turkeys in a Sportsman's Paradise.*

By Henry P. Bridges. A. S. Barnes & Company, New York. $10.00. xii + 210 pp.; ill. 1953.

The Woodmont Rod and Gun Club, in Hance, Maryland, is a sportsman's Mecca. Six Presidents of the United States (Garfield, Arthur, Harrison, Cleveland, Hoover, and Franklin D. Roosevelt) have hunted there since it was first organized in 1870. The author of this book of a hunter's reminiscences reorganized the Club in 1908 and has been identified with it ever since. The book deals with his experiences in hunting deer, small game, and "vermin," and in fishing, but over and above all else, in raising and hunting the wild turkey. More than any other man, he saved the North American wild turkey from extinction. The author writes simply and with an excellent style. His philosophy is that of the enlightened hunter and game conservationist. His book makes an excellent gift for the boy who loves hunting and fishing and may serve to make him a less heedless killer. It may also be predicted that, because of the numerous sidelights on local American history preserved in the book, it is fated to become a widely sought-after volume of Americana.

BENTLEY GLASS

ANIMAL GROWTH AND DEVELOPMENT

ANALYSIS OF DEVELOPMENT.

Edited by Benjamin H. Willier, Paul A. Weiss, and Viktor Hamburger. W. B. Saunders Company, Philadelphia and London. $15.00. xii + 736 pp.; ill. 1955.

In his Valedictory as Editor of "The Scientist's Book Shelf" (*The American Scientist*), Kirtley F. Mather recorded his finding that only a few minutes are required to get sufficient knowledge of a book to write a noncommittal or faintly commendatory review of it, whereas it takes hours of careful reading to prepare oneself for writing either a strongly favorable or a sharply critical review. Since it is likely that this view is widely held, I feel obliged to state in my own defense that my moderate and not overwhelmingly enthusiastic review of *Analysis of Development* should not be taken as suggesting that I spent only a few minutes with it, for I made a serious effort to read every one of the more than 700 pages. My lukewarm reaction to certain sections of this long-awaited book may indicate that I should have summoned to my assistance a number of guest reviewers, for few reviewers, no matter how broad their interests, can be qualified to evaluate the literature of all areas of modern embryology.

In 14 sections, 29 chapters, 735 pages (including an adequate subject index), twenty-eight well-known biologists have attempted to portray present-day views of animal development. The editors, B. H. Willier,

Paul Weiss, and Viktor Hamburger, make clear the objectives of the book in their statement of guiding aims addressed originally to the authors: "The purpose of this book is to present a modern *synthesis* of our knowledge of the principles and mechanisms of development. In these days of rapidly expanding information it becomes increasingly difficult to keep perspective. It is urgent, therefore, that this book provide not just another source of information but that it view the phenomena of development from a common perspective so that the reader may recognize the great main lines and inner coherence of the field above the multiplicity of often unrelated details of which the field seems composed when viewed too closely." The editors were well aware in planning the book that such a collaborative work might sacrifice unity and integration; they hoped, however, that this imperfection would be balanced by the advantage of having an authoritative presentation of each topic. It is not feasible to consider here the organization and context of the individual chapters for which each author was responsible. However, it is regrettable that not all of the authors took seriously the editors' charge to emphasize synthesis and critical evaluation. *Analysis of Development* is a mosaic in which the individual contributions are far too uneven in quality. There is too great a range in breadth and depth of comprehension and in cogency of conclusions and generalizations, as well as in clarity of presentation. For example, the disparity between Dorothea Rudnick's lucid and thought-provoking account of Progressive Differentiation in Teleosts and Birds and the obscure chapters on Regeneration in the Vertebrates and The Determination of Size, is quite striking. To me, the following chapters appear to conform to the spirit and objectives of the volume unusually well: Progressive Differentiation in Insects (D. Bodenstein); Energy Exchange and Enzymes in Development (E. J. Boell); Urinogenital System (R. K. Burns); Metamorphosis (W. Etkin); and, at the risk of being accused of favoritism, I include the chapter on the Ontogeny of Endocrine Correlation, by B. H. Willier. The chapter on Progressive Differentiation in Amphibians, written jointly by J. Holtfreter and V. Hamburger, is a thoughtful and well-considered treatment of a subject in which the data are diffuse and contradictory. The clarity of exposition in this chapter came as a pleasant surprise to the reviewer and may surprise others familiar with the widely divergent styles of writing of the co-authors. (I have heard it said recently that it is an even greater surprise that the authors remained good friends when the chapter was completed.)

It may be useful to record some observations on the over-all plan and scope of the book. First, it may be questioned whether the section on Cellular Structure and Activity, especially the chapters dealing with Cell Constitution and Cellular Metabolism, are sufficiently pertinent to the main theme of the book to be set apart as separate chapters. About one-third of this material might have been considered profitably in other chapters, e.g., the discussions of physico-chemical considerations of morphogenetic processes and regulation of metabolism in development. Both chapters are well written; however, equally coherent presentations of cellular structure, glycolytic and oxidative metabolism, etc., are available in a number of cytology and biochemistry textbooks. These chapters add little of a conceptual nature to the book. It seems wasteful, for example, that considerable space is devoted to such familiar topics as the colloidal organization of protoplasm, intermediary metabolism of carbohydrates, and pathways in the metabolism of pyruvate.

Some readers may object to the separation of the discussion of The Nucleus and Cytoplasm in Development into two chapters, viz., The Role of Nucleus and Cytoplasm, and Gene Action. This artificial separation tends to emphasize the distinction between the embryological and the genetic approaches, although it would seem more desirable to stress their intercommunity. This is not intended as a criticism of the authors of these chapters, who have successfully carried out their individual assignments. It appears likely, however, that a more penetrating treatment might have resulted from a unified approach. It is not a little surprising to find such pertinent topics as bacterial transformations and transduction almost entirely ignored.

Albert Tyler has struggled valiantly with a chapter dealing with the Ontogeny of Immunological Properties. It is doubtful that a better presentation of the subject could have been achieved. However, there is a serious question as to whether the material now available warrants the inclusion of a separate chapter. It might have been more appropriate to have included a broader consideration of problems of specificity in development, drawing together data from a number of experimental approaches. The author clearly was hampered in approaching his subject by the limitation of the topic; as a result, his treatment of the material tends to be encyclopedic in character.

The chapters by Costello (Cleavage, Blastulation and Gastrulation) and Watterson (Progressive Differentiation in Selected Invertebrates) overlap considerably as they now stand. Several readers have suggested that it might be desirable to combine these chapters. On the other hand, it might be preferable to retain the present division, but to reorient the former chapter so that greater attention is paid to the physical forces operating in early development.

Since *Analysis of Development* is, in the words of the editors, "primarily dedicated to the pioneering spirit of those students who will hereafter enter the field of development and growth," consideration should have been given to the challenging problems of morphogenesis. Although such questions as the physicochemical basis of morphogenetic movements, oriented cell

movements and pattern formation, and cell and tissue affinities, are taken up at scattered points in several chapters, there is no integrated discussion of these problems. This omission is probably the most conspicuous shortcoming in the planning of the book. 115 pages are devoted to progressive differentiation, and it seems fitting that at least one chapter should have been allotted to morphogenetic movements. Admittedly, the available data do not permit any great generalizations, but in view of the importance of presenting unsolved problems a few pages might have been well spent.

Perhaps it is asking too much to expect that in such a collaborative effort all of the contributions should be of the highest caliber. Perhaps it is unfair to penalize the many who labored long and well for the imperfections of a few. With all of the criticisms that may be directed against it, *Analysis of Development* is a useful book, which can, on the whole, be recommended to all advanced students of development. Many of the chapters are provocative, and in future years the ideas expressed in them should serve to stimulate new investigations.

JAMES D. EBERT

ENTWICKLUNGSPROBLEME.

By Leopold von Ubisch. Gustav Fischer Verlag, Jena. DM 12.70 (paper). 196 pp.; ill. 1953.

Von Ubisch takes up in this book three topics in turn: in his own language, *Plasmareifung, Determinationsproblem, Gradientheorie und Zuordnungsproblem.* One of the great merits of his discussion is that, unlike so many others, it concentrates on the problems as such, subjugating to the consideration of these both the presented data and their interpretations.

The experimental data chosen as factual examples have been selected primarily from investigations on invertebrate forms, and they are described clearly, carefully, and critically. The interpretations based on them are however sufficiently broad to be applicable to a general theory of development. If von Ubisch's general concepts of development center heavily on gradient theory, they show the virtue of doing so coherently, and the data presented provide considerable evidence for the validity of the interpretations based upon them.

These data have been chosen almost exclusively from the field which the new generation of embryologists seems to refer to as "classical" experimental embryology. A question arises, in connection with this book and others like it, as to whether this adjective may prove less derogatory to the *Fragestellungen* of experimental embryology than its employers intend. Tadeusz Biliekiewicz wrote, slightly over two decades ago, a charming discussion of the embryology of the 17th and 18th centuries under the title *Die Embryologie im Zeitalter des Barock und des Rokoko* in which he raised some questions concerning embryological style which might well be directed toward investigations of the 20th century.

If the experimental embryology of the first two-thirds of the 20th century seems classical in connotation to the chemical embryologists, what do they define as its romantic equivalent? They probably hardly so consider the biochemical approach, which however sometimes betrays a debt to some romantic origins in its attempt to account rather for similarities than differences in what it calls fundamental embryological mechanisms. And to what parallel do they relegate the morphological styles and techniques which provide the line and the dimension and even the dynamic movement which give meaning to all that the experimentalists and biochemists alike superimpose on these? And who, if it is not rude to inquire, do they consider to be the impressionists and the abstractionists and the new *avant garde*?

If the analogies between styles in art and literature, on the one hand, and techniques in embryology, on the other, were to be labored more fully by those who refer so blithely to classical experimental embryology (and who, to do them justice, probably mean no more than to disparage it as old-fashioned), baroque might be found to be a fitter adjective than classical. The thesis could easily be maintained that embryos, after all, are fairly baroque creatures. Witness, from the structural point of view, a brachiolarian larva; or, from the functional, some of the regulatory processes whereby abused embryos find a long way around when the shorter way is experimentally made infeasible. It is in the intrinsic nature of experimental embryology to find diversity an integral aspect of the fundamental pattern of organization underlying the whole, rather than something constructed of spirals and projections and prominences encrusting it as an external shell. It sees, and this is the element of baroque in *its* character, diversity as constituting the pattern and not to be peeled off from it as something separate. And if the line of which the pattern is fabricated proves to be a gradient line, which happens to be the opinion of von Ubisch, this is accounted for merely by the fact that, as he so convincingly demonstrates, the egg still in the 20th century exhibits polarity and gradiency among the most manifest attributes of its organization.

There are no embryologists today who are more intelligent than von Ubisch, and his book is a book written by an embryologist for embryologists. It is a valuable supplement to other available modern treatises, and well deserves a place on the bookshelves of every working embryologist.

JANE OPPENHEIMER

BIOLOGICAL SPECIFICITY AND GROWTH. *The Twelfth Symposium of The Society for the Study of Development and Growth.*

By A. M. Schechtman, M. W. Woerdeman, M. R. Irwin, S. C. Shen, R. Brown and E. Robinson, J. R. Raper, J. A. Harrison, W. H. Taliaferro, H. S. N. Greene, P. Weiss, R. Briggs and T. J. King; edited by Elmer G. Butler. Princeton University Press, Princeton. $5.00. viii + 233 pp. + 14 pl.; text ill. 1955.

To students of development, weary of hurried 10- or 15-minute papers and limitation of discussion at large multi-society meetings, the annual symposia of the Society for the Study of Development and Growth offer an opportunity for informal, deliberate consideration of the important problems of the field, presented by representatives of widely divergent scientific disciplines. Unfortunately, it is impossible to capture fully the flavor and vigor of the meetings in the chapters of the annual symposium volume. Nevertheless, the publication of each year's papers is awaited with interest, for they usually represent an authoritative assessment of the knowledge of the subject. In the present volume, at least 6 of the papers are of general interest and maintain the standards readers have come to expect. S. C. Shen assumes that the careful determination of enzyme activity under optimal conditions usefully represents the enzyme content, and then proceeds through a neatly illustrated correlation of enzyme content with development in an experimental manner aimed at the analysis of differentiation in quantitative terms. At the same time, he does not ignore either the possible role of enzymes as structural proteins or the differentiation of organized enzyme complexes. His contribution is one of the more thoughtful appraisals of the subject in recent years. The lucid survey by J. R. Raper of gene-controlled specificities in the sexual differentiation of plants suggests the complexity of the genetics which we must expect to apply in the more general problems of differentiation. R. Briggs and T. J. King detail the techniques, literature, and prospects of nuclear transplantation creatively. M. R. Irwin clearly distinguishes the immunological and the genetic aspects of immunogenetics. However, it might have been well to point out more sharply that the use of immunogenetics in problems of development may more exactly define the relatively direct relation of genes to their cellular antigens, a relation now resting on purely genetic grounds. A. M. Schechtman rightfully opposes the concept that the detection of a tissue antigen necessarily gives any information about the causal factors of the differentiation of that tissue. But he does so in an ambiguous way by suggesting that knowledge of the genic control of erythrocyte antigens justifies their classification as noncausal. Regardless of the genetics the essential point is that the possession of different erythrocyte antigens does not influence the differentiation of erythrocytes in any known way. And it should be added that as yet the pertinent inferential value of the erythrocyte antigens stems from their technical convenience and not from biological propositions. In addition, Schechtman emphasizes the importance of the transfer to the embryo of heterosynthesized macromolecules from maternal tissues. Whether the macromolecules of adult origin are merely end-products of differentiation or take an active part in the mechanism of differentiation remains to be established. Paul Weiss reassesses the older evidence and presents new findings in support of the existence of a cell-type specific chemical mechanism of correlating growth processes among homologous cell types.

R. Brown and E. Robinson emphasize a distinction between growth and protein increase in plant cells and demonstrate in vitro that both growth and invertase activity can be dependent on sucrose. J. A. Harrison mentions two interesting effects of antibody: (1) the acquired insensitivity of some antibody-treated protozoa to the continuing presence of antibody, and (2) the antibody stimulation and inhibition of division in *Tetrahymena*. No detail or reference is given for (1). In his discussion of the immunobiological approach to problems of induction and differentiation, M. W. Woerdeman again briefly considers his most challenging finding that while extracts of head ectoderm and isolated eye vesicles of young axolotl neurulae (taken before the development of lens placodes) do not react separately with antiserum to adult lens, a mixture of equal parts of ectoderm extract and extract of eye vesicles shows a positive precipitin reaction with the antiserum after incubation at 37°C for 24 hours. Although this observation was made first in 1950, details of the experiment have not been given. If confirmed, this finding opens up a wide range of fascinating experiments. Woerdeman also discusses the reports by Langman that tissue fragments of rabbit embryos cultivated in heterologous (cat) serum proteins incorporate the intact foreign proteins which can be detected by serological methods. One is not wholly convinced, however, after reading Langman's publications, that non-specific adsorption of protein was eliminated as a possible explanation of the results.

Parasitology would seem to be a profitable field for the elucidation of specificity in both protozoan and host cells by experimental adaptation of parasites to foreign sites in common hosts, foreign hosts, and in vitro environments, but its didactic possibilities are not emphasized in Taliaferro's lecture on natural selection among parasites. H. S. N. Greene's account of his results in transplanting adult, embryonic, hyperplastic, precancerous, and cancerous tissues suggests that careful analysis of the terminology and quantitative possibilities of transplantation is badly needed.

R. F. RUTH & JAMES D. EBERT

GESTATION. *Transactions of the First Conference, March 9, 10, and 11, 1954, Princeton, N. J. Edited by Louis B. Flexner. Josiah Macy, Jr. Foundation, New York.* $5.00. 238 pp. + 4 pl.; text ill. 1955.

The first of several Macy Conferences on *Gestation* concerned the physiology and morphology of the placenta. Nineteen authorities from the United States and abroad joined in a series of lively informal discussions stimulated by three invitation papers presented by Flexner, A. St. G. Huggett, and E. C. Amoroso. The transcript of the meetings, with all interjections, questions, and comments, has been published almost in entirety.

Flexner discussed sodium transfer across the placental barrier of the guinea pig and man, as elucidated by utilizing radiosodium as a tracer introduced into the maternal plasma and recovered in the fetus. Data were also presented for iron transfer (introduced as β_1-globulinate), and allusions were made to the transport of radioactive phosphate and of heavy water. From a study of the migration rates, Flexner concludes that sodium crosses into the fetal circulation as a result of physical diffusion, and without active transfer. The evidence for such passive diffusion of iron and phosphate, however, appears less satisfactory, and this touched off a spirited discussion concerning the limitations of a purely physical, non-metabolic mechanism of exchange. Few conclusions were reached with respect to the nature of ion exchange across the placenta, and the difficulties may be attributable to inadequacies of current methods, the complex structure of the placental membranes, and the points of view of the participants. Much more work is obviously needed in a comparison of the migration rates of similar ions and of comparable organic substances across the normal and perhaps the metabolically inhibited placenta before many conclusions may be reached concerning the relative importance of the forces that tend to establish a Donnan type of equilibrium as contrasted with an active cellular transfer mechanism in moving substances through this reproductive organ. A pronounced decrease in sodium transfer across the human placenta at about 35 weeks (gestation age) suggests physiological aging. This disclosure led to an interesting discussion of the time of mammalian birth in relation to the age or life span of the placenta. In another diversion, the older placenta, far from being considered a "barrier," was credited with six or seven possible methods and routes of exchange—from the diffusion of small molecules to the transfer of organic structures by pinocytosis and leucocytic migration.

The second general subject of the Conference was Huggett's presentation of sugar transport and the production of fructose in the ungulate placenta. Large quantities of fructose (30 to 200 mg. %) are found in the fetal blood of sheep, for example, and this has been traced to conversion by the placenta of glucose in the maternal plasma. Fructose can pass both ways across the ungulate placental membranes, and the mechanism seems to be one of active transport, perhaps mediated by intracellular carriers, as envisaged by Widdas. Glucose, which is found in fetal sheep blood in moderate quantities, is probably transferred also by means of an active, metabolic process. The small amounts of fructose in the blood of the human fetus are produced in the placenta (Villee). The available evidence indicates that in man glucose is transferred from the maternal to the fetal plasma by active processes, over and above physical diffusion forces. Davies, however, in discussing data on sugar transfer in the rabbit, indicates that diffusion alone will suffice to account for the transfer of glucose across the placenta and its accumulation in the fetus.

A lack of conformity among the data and the variety of interpretations represented emphasize again the differences which exist in these processes in different animals and at different stages of gestation. On the latter point, Villee presented some enlightening results bearing on the aging of the human placenta. The data involve decreases in oxygen consumption, in relative water content, and in accumulated glycogen.

Amoroso's contribution to the comparative anatomy and histology of the placenta is a classic. In discussing the placenta as an adaptation for viviparity among the invertebrates and lower vertebrates, he included much anatomical detail, many fine illustrations, and examples from *Peripatus* to the Australian bandicoot. The wide range of subtle morphological variations and the developmental changes in the placentae of higher mammals underscore the inadequacies in the half-century old classification of placental types by Grosser. Since, however, no complete scheme can as yet be intelligently organized, and since Grosser's main points (recognizing their limitations) are of some traditional use and are practical at least for physiologists, there seems some reason to bear Grosser's classification in mind and not to throw it overboard, as some discussants at the Conference wished—at least not until a better scheme has been devised.

The usefulness of these Transactions is further augmented by the inclusion of a list of human placental enzymes with references, and arranged according to the nomenclature of Hoffmann-Ostenhof. A satisfactory working index is also included. The format and editing of *Gestation* are up to the usual high standards of Macy Conference Transactions. A reader, not attending the Conference, however, might wish that some attention in the future be given to the possibility of a summation of salient points. The advantages of publication of the entire informal proceedings are frequently overshadowed by the feeling that the discussions are getting nowhere. Indeed, the opening consideration of an appropriate definition of the "placental membrane" is

left in an even more confused state at the close of the volume. Perhaps the outcome of future conferences on *Gestation* will be a consolidation of principles and ideas, which may then be more adequately organized for the scientific "fringe" not fortunate enough to attend these valuable meetings.

DAVID W. BISHOP

HUMAN DEVELOPMENT.

By John P. Zubek and P. A. Solberg. McGraw-Hill Book Company, New York, Toronto, and London. $6.00. viii + 476 pp.; ill. 1954.

This textbook in human development is marked by four main characteristics. First, it deals with both phylogenetic and ontogenetic development, although its coverage of ontogenetic development is by far more complete than its coverage of phylogenetic differences.

Second, it covers the entire range of human life from birth to senescence. The inclusion of changes during maturity and old age is one of the author's main objectives. They do consistently cover the period of maturity and senescence although they are naturally limited by the amount of available knowledge concerning the later years.

Third, the book differs from other developmental texts written by behavioral scientists in the relative amount of space given to physical and biological development. Three chapters are devoted to neural, glandular, and physical development, and the next 3 chapters, on motor and sensory development, contain a great deal of relevant information about the physiological aspects of development.

Fourth, the book is primarily a description of age differences in physical, intellectual, and emotional characteristics, although some material on the developmental process is included. The problem of maturation and learning is frequently discussed, and developmental changes in the learning process are described; but there is very little material describing concretely the consequences of particular antecedent conditions, for example, institutionalization on later personality development.

This logical organization gives the book clarity of outline and at the same time a somewhat academic tone. The student may well be interested in many of the facts presented and may see the very great potential significance of the research the authors report, but he will not find very much material whose relevance for the immediate problems of child management or guidance is made explicit.

ALFRED L. BALDWIN

GROWTH OF PROTOZOA. *Ann. N. Y. Acad. Sci., Vol. 56, Art. 5.*

Edited by Roy Waldo Minor; consulting editor, S. H. Hutner; 61 contributors. The New York Academy of Sciences, New York. $4.50 (paper). Pp. 815–1094; ill. 1953.

Space will not permit a full listing of the contents of this publication, comprising the 35 papers presented at a Conference of the New York Academy of Sciences held in October, 1953. The title adequately indicates the nature of the contents. The participants included most of the well-known protozoologists of the United States who are actively interested in ecological, nutritional, and biochemical problems rather than systematic or genetic aspects. It is a volume of tremendous value, or would be except for one deficiency: it lacks an index. In a collection of papers running to more than 250 pages, which ought to possess some permanent value as a reference work, the omission of an index is a fatal error. The attention of the editors of this otherwise exemplary series has been directed to this matter repeatedly. It is high time that if the N. Y. Academy of Sciences is to plan to continue to publish symposia numerous and of high potential value, it should seek the services of an indexer and provide the funds to have this essential work done.

BENTLEY GLASS

INSECT METAMORPHOSIS. *Smithsonian misc. Coll., Vol. 122, No. 9. Pub. 4144.*

By R. E. Snodgrass. Smithsonian Institution, Washington, D. C. $1.20 (paper). iv + 124 pp.; ill. 1954.

During the past thirty years the most striking advances that have been made in our understanding of the metamorphosis of insects have concerned the physiological mechanisms by which the observed changes are controlled. But this is only one side of a very large problem, the morphological, phylogenetic, evolutionary, and adaptive aspects of which are equally important. In this excellent monograph R. E. Snodgrass condenses a life-time of experience and judgment in this field. The part played by hormones in regulating insect growth is summarized very briefly. The book is mainly concerned with reviewing the morphological background, both in the more primitive orders and in the Endopterygota. There are chapters also on larval heteromorphosis and on the pupal transformation as it affects all the different organ systems. Snodgrass takes the view that holometabolism is just one type of metamorphosis; the fact that it occurs among Hemiptera in the male coccid, and also in the Thysanoptera, does not relate these insects taxonomically to each other or to such typical holometabola as the Coleoptera, Lepidoptera, Diptera, and Hymenoptera. He accepts the view that the reason for holometabolism is to be found in the disparity in the muscular system between the young insect and the adult. He also accepts the view, which fits in with the

evidence from insect hormones, that the pupa is to be regarded as a first adult instar.

V. B. WIGGLESWORTH

ANIMAL MORPHOLOGY

MCFADYEAN'S OSTEOLOGY & ARTHROLOGY OF THE DOMESTICATED ANIMALS. *Fourth Edition.*

Edited by H. V. Hughes and J. W. Dransfield. Baillière, Tindall & Cox, London; [The Williams & Wilkins Company, Baltimore]. $5.00. viii + 288 pp.; ill. 1953.

The staying qualities of this work, first published in 1887, are a sufficient testimonial to its solid character. Those who were entrusted with the present revision have tried to bring the nomenclature into line with modern usage and to supply new figures. More attention has been given to the development of the bones. The first section, of 7 chapters, is on Osteology; the second, of 4 chapters, on Arthrology. Various animals are used to exemplify the nature of the skeletal structure. Thus the chapter on The Vertebral Column devotes a major section of the discussion to the horse, with shorter sections thereafter on the vertebral column of the ox, the sheep, the pig, the dog, and the cat. This plan is followed in the succeeding chapters on other major portions of the skeleton. There is a special chapter on the Skeleton of the Domestic Fowl. The section on Arthrology is devoted almost exclusively to the joints of the horse.

This book, apart from its intended use in the education of veterinary doctors, may well form a valuable reference work in the study of comparative anatomy in departments of biology and zoology.

THE CIBA COLLECTION OF MEDICAL ILLUSTRATIONS. *Volume 1, Nervous System. A Compilation of Pathological and Anatomical Paintings.*

By Frank H. Netter; foreword by John F. Fulton. Ciba Pharmaceutical Products, Summit, N. J. $6.00. 143 pp.; ill. 1953.

THE CIBA COLLECTION OF MEDICAL ILLUSTRATIONS. *Volume 2, Reproductive System. A Compilation of Paintings on the Normal and Pathologic Anatomy.*

By Frank H. Netter; edited by Ernst Oppenheimer; foreword by John Rock. Ciba Pharmaceutical Products, Summit. $13.00. xvi + 285 pp.; ill. 1954.

The interesting medical illustrations of Frank H. Netter have become increasingly familiar in recent years, chiefly in the form of isolated brochures on restricted topics. These two volumes, which are the beginning of a series expected to cover the "anatomy and pathology of all the systems comprising the human organism," represent a systematic approach to entire organ systems. The paintings are simple, clear, accurate, well chosen for the field, and remarkably even in quality. The color reproduction is excellent. Although primarily illustrative, these books have a running text which describes the salient features of the plates.

It is difficult to evaluate this work with reference to its pedagogical value. From the scholarly point of view there is no comparison to illustrated texts or even to atlases, such as those of Spalteholz and Sobotta, which were compiled primarily for systematic illustration. The presentation, while accurate, certainly does not match the systematic and scholarly approach of Brödel. It is not clear what place in medical illustration these volumes will eventually assume. But in view of the careful and skillful presentation so evident throughout, Netter's work should be encouraged and followed with more than ordinary interest.

F. N. LOW

LEHRBUCH UND ATLAS DER ANATOMIE DES MENSCHEN. *Volume I. Allgemeines, Skeletsystem, Muskelsystem, Gefässsystem. Nineteenth Edition.*

By Fr. Kopsch. Georg Thieme Verlag, Stuttgart; [Intercontinental Medical Book Corporation, New York]. DM 64.50. viii + 736 pp., ill. 1955.

The famous Rauber-Kopsch anatomy has now appeared in what is essentially its 19th edition but is now under the sole authorship of Kopsch. Its recognized quality has improved through its many editions, and the present one continues the tradition of exceptional worth. It is still the fine German anatomy text that it always has been. Although the Preface describes extensive changes and new reproduction of figures, scholars familiar with previous editions will have little difficulty recognizing an old friend. Its quality as a book is unusually fine. The reproductions, both in color and otherwise, are technically excellent, and the entire volume is printed on high quality glossy paper. An old landmark of German scholarship has again been reworked and edited, and the result should insure its continued popularity.

F. N. LOW

PRIMARY ANATOMY. *Third Edition.*

By H. A. Cates and J. V. Basmajian. The Williams & Wilkins Company, Baltimore. $5.75. xiv + 339 pp. + 4 pl.; text ill. 1955.

The third edition of this undergraduate textbook was largely prepared by J. V. Basmajian after the death of H. A. Cates in July, 1953. It is intended for students in physiotherapy, occupational therapy, physical and health education, nursing, etc. About one-third of the 440 illustrations are new cuts, a new section on embryology has been added, and major changes were

made in the section on muscles. This text, with its clear line drawings and its straightforward presentation of anatomy, should continue to serve as an adequate elementary treatment of its subject material.

F. N. Low

ENDOTHELIUM. *Its Development, Morphology, Function, and Pathology.*

By Rudolf Altschul. The MacMillan Company, New York. $3.50. xvi + 157 pp.; ill. 1954.

This small monograph contains an extensive account of endothelium under 8 chapter headings, and closes with a bibliography of 359 references. It has a great deal of information about endothelium in it, but it conspicuously lacks critical coherence and purposeful interpretation of the broader aspects of the field. The result is an uninspired, pedestrian account of its subject, valuable chiefly for factual information and for the bibliography.

F. N. Low

LABORATORY MANUAL FOR HISTOLOGY.

By J. F. Smithcors. Burgess Publishing Company, Minneapolis. $3.00 (paper). ii + 101 pp. 1954.

This manual is intended for a course in which embryology is integrated with histology, with emphasis on the latter. Directions for orientation are followed by questions about details. Alternate blank pages may serve for drawings. This elementary guide seems to be written carefully enough. But, since the text and questions refer to specific preparations (nowhere listed by description), its usefulness will naturally be limited with any slide collection other than the one for which it was originally written.

F. N. Low

ANIMAL PHYSIOLOGY

CONNECTIVE TISSUES. *Transactions of the Fifth Conference, February 1954.*

Edited by Charles Ragan. Josiah Macy, Jr. Foundation, New York. $4.25. 222 pp. 1954.

The fifth and final conference on connective tissues, held in February 1954, was centered around the following discussions: B. W. Zweifach, The Exchange of Material between Blood Vessels and Lymph; M. Gaudino, Interstitial Water and Connective Tissues; and G. Asboe-Hansen, Hormonal Effects on Connective Tissues. Zweifach reports on rather selected aspects of his impressive series of observations. As usual, many interesting points are brought out in the group interchange, but in this conference rather a minimal amount of coherent information emerges, except by implication as "background."

EVELYN HOWARD

BONE. *An Introduction to the Physiology of Skeletal Tissue. The Scientist's Library: Biology and Medicine.*

By Franklin C. McLean and Marshall R. Urist. The University of Chicago Press, Chicago. $6.50. xii + 182 pp. + 1 pl.; text ill. 1955.

This is an excellent little volume, and it constitutes a most promising beginning in a new series of publications: The Scientists Library: Biology and Medicine. The purpose of the series is to provide authoritative information about the growth and status of various subjects, with a textual approach somewhat different from that ordinarily used by the specialist. "The authors have been asked to emphasize introductory concepts and problems, and the present status of their subjects, and to clarify terminology and methods of approach, instead of limiting themselves to detailed accounts of current factual knowledge. The authors have also been asked to assume a common level of scientific competence rather than to attempt popularization of the subject matter." In the present instance there has been achieved a very stimulating presentation of the manifold aspects of the physiology and biochemistry of bone. The senior author has long been concerned in "a conscious effort to bridge some of the gaps between the chemical and morphological approaches to an understanding of bone." Information is brought together from morphology, histochemistry, enzyme chemistry, experimental embryology, crystallography, and electron microscopy. Historical treatment has been reduced to a minimum, but the current literature has been critically analyzed and evaluated in a way which should make this volume a welcome companion to biologists and also to those concerned with the healing of fractures and the pathological aspects of bone reactions.

EVELYN HOWARD

PHYSIOLOGY AND BIOCHEMISTRY OF THE SKIN.

By Stephen Rothman. The University of Chicago Press, Chicago. $19.50. xiv + 741 pp.; ill. 1954.

This is a fairly critical review of an enormous literature on the subject. The author reveals no concepts or patterns which might emerge from the mass of information. It is stated in the Preface that there would be great emphasis on the historical approach. This objective is attained, perhaps so successfully as to detract to a considerable extent from the potential value of the book. For example, the early work on the secretion of urea in sweat is reviewed in extenso, whereas the important recent contributions of Schwartz

are given only passing mention. Although the phenomenon has been well known for several years, the excessive electrolyte loss in the sweat of patients with cystic fibrosis of the pancreas is not even mentioned. In spite of a general reluctance of the author to try to find relationships among the various phenomena reported, this book should be an extremely valuable reference work, and its extensive bibliographies will be of great help to research workers as well as clinicians.

SAMUEL P. BESSMAN

RENAL FUNCTION. *Transactions of the Fifth Conference, October 14, 15, and 16, 1953, Princeton, N. J.*

Edited by Stanley E. Bradley. Josiah Macy, Jr. Foundation, New York. $3.75. 218 pp.; ill. 1954.

The fifth and final conference on renal function was held in October 1953, and centered around the following discussions: John A. Luetscher, Jr., The Nephrotic Syndrome; B. F. Miller, The Problem of Kidney Transplantation; and G. M. Bull, Acute Renal Failure. Although the topics are primarily clinical, the considerations are in part on a level which should be of interest to physiologists.

EVELYN HOWARD

NERVE IMPULSE. *Transactions of the Fourth Conference, March 4, 5, and 6, 1953, Princeton, N. J.*

Edited by David Nachmansohn. Josiah Macy, Jr. Foundation, New York. $4.00. 224 pp.; ill. 1954.

The three principal discussants at the Fourth Conference on the Nerve Impulse were George Wald, on the Mechanism of Vision, Hallowell Davis on the Mechanism of Hearing, and Yngve Zotterman on Sensory Receptors. As in earlier volumes in this series, the discussions are recorded verbatim. Judging from the number of interruptions, the conference was a lively one. In print, however, the result is distracting and difficult to read. This volume, like the others, lacks an index, an omission which also limits its usefulness.

Despite the shortcomings of this book as a medium of information, the specialist who is working with sensory mechanisms or with the nerve impulse is almost certain to find something of interest here. There is, for example, a very lively argument stimulated by Wald following Davis' presentation of an electrical model of excitation for auditory nerve impulses. Before they are through, the protagonists have posed some fundamental questions about the value of physical models for biological systems. Whatever your private position in this matter, you are likely to find the argument thought-provoking and even amusing.

A. CHAPANIS

PHARMACOLOGY IN MEDICINE. *A Collaborative Textbook. Edited by Victor A. Drill. McGraw-Hill Book Company, New York, Toronto, and London.* $19.50. xiv + 18 Parts + 26 pp.; ill. 1954.

For a number of years now many pharmacologists have been troubled with the textbook situation. There are several reasons for the difficulty in selecting one suitable for use by medical students, one of the more compelling ones being that most medical schools are behind the times in adjusting their curricula (or entrance requirements) to keep pace with recent advances in the basic and medical sciences. This makes the situation particularly difficult in teaching pharmacology, but the same may be said about the other basic sciences. An examination of the bulletins of medical schools will show that since 1930 there has been a reduction in the number of hours allotted to pharmacology, despite the fact that during the past 20–25 years this field has witnessed more dramatic advances (and expansion) than any other of the medical disciplines. Although most instructors have sought to remedy this situation by deleting, or reducing considerably the time allowed to, such material as is now considered obsolete or of little importance (pharmacognosy, pharmacy, and even prescription writing), they are still faced with inadequate time and a "packaged" course in pharmacology. A number, therefore, are reluctant to use a "comprehensive" textbook for such a course that is usually given in a 12-week or 17-week session. As a result of this situation, a few condensed textbooks have appeared and become popular, some of which are quite well prepared. Recently, a number of the larger, more comprehensive textbooks have been published; the one above, edited by Drill, is an example.

My own preference is for the comprehensive textbooks. Generally, they will have a longer, more lasting value to medical students and will serve as a valuable reference book in the student's library. Furthermore, I prefer books that cover the subject in a more scholarly manner and present in detail all sides of a controversial subject. In many ways, the type of textbook used sets the standard of a course—but, of course, it is not the only factor.

The matter of choice among the available comprehensive textbooks is difficult. Probably most instructors will want to compare the present textbook edited by Drill with the 2nd edition of Goodman and Gilman. In the first place, the errors of commission or omission in either are not too serious. Depending upon one's point of view, objections may be found to the handling, in both textbooks, of insulin. I, for one, do not consider a treatment of this subject adequate that does not consider the contributions of Drury and his collaborators. However, what is of greater concern to potential users of either of these two important books is the general style of presentation.

The textbook edited by Drill is the result of the

work of over 80 contributors. For instance, the sections on specific chemotherapy are the work of 13 different authors; that on the endocrines, of 9; the autonomic nervous system, of 6; sedation, hypnosis, and analgesia, of 8; and so for the other sections. Goodman and Gilman had relatively little outside help, but of course they had a first edition to rely on. It would be expected, therefore, that Drill's book would give more detailed consideration to many subjects, whereas Goodman and Gilman would have better continuity between the various parts. Yet a comparison of the sections dealing with anesthesia in the two books shows that although Goodman and Gilman touch only lightly on theories of anesthesia, they do a job on this subject that is as excellent and thorough as the one they did in their first edition. Similarly, I prefer their treatment of the autonomic nervous system, particularly their introduction and development of this subject. I find also desirable the separate section dealing with drugs used in neoplastic disease, a section that is absent in Drill's textbook. As for the handling of the rest of the subjects, it is a toss-up between the two. My choice for the course given in the University of Puerto Rico is Goodman and Gilman, but your students won't suffer too much if you select Drill's—other than the fact that it is an exceedingly heavy book to carry around.

DAVID B. TYLER

ANIMAL NUTRITION

THE VITAMINS. *Chemistry, Physiology, Pathology. Volume II.*

Edited by W. H. Sebrell, Jr. and Robert S. Harris. Academic Press, New York. $16.50. xiv + 766 pp.; ill. 1954.

Volume II of this 3-volume work is a continuation of the alphabetical compilation of the vitamins, with the chief emphasis on their chemical properties and biological characteristics (Vol. I, *Q.R.B.*, 30: 83, 1955).

Almost all of the various aspects of choline, including its chemistry, industrial preparation, biochemical systems, specificity of action, biogenesis, estimation, standardization of activity, occurrence, effects of deficiency and requirements of animals, are covered by Wendell H. Griffith and Joseph F. Nyc. The effects of a choline deficiency in man, its pharmacology, and the requirements of human beings for choline are handled by W. Stanley Hartcroft, Colin C. Lucas, and Charles H. Best. As respects the vitamin D group, the chemistry, industrial preparation, estimation, and standardization of activity are discussed by Charles E. Bills, while the effects of deficiency, the chemical pathology and pharmacology, and the requirements are dealt with by James H. Jones, Benjamin Kramer, and Abram Kanof. The extent of our knowledge of the role of vitamin D at the biochemical level is adequately reflected by the absence of any section on biochemical systems. The essential fatty acids (linoleic acid, linolenic acid, archidonic acid) receive a relatively short page allotment contributed by Ralph T. Holman, Arlid E. Hansen, and George A. Emerson. The reviews of the different aspects of the inositols, by Henry A. Lardy, Erwin Chargaff, E. R. Weidlein, Jr., Arthur H. Livermore, E. E. Snell, T. J. Cunha, and A. T. Milhorat, are outstanding. The vitamin K group is presented by H. J. Almquist, Robert S. Harris, and Charles A. Owen, Jr. At this early date one of its most important sections, biochemical systems, is already out of date, in view of the growing evidence implicating vitamin K in electron transport, oxidative phosphorylation, and photosynthesis. The significant and stimulating investigations centering around niacin and its important coenzyme forms are given excellent treatment in this volume. J. M. Hundley covers most of the phases of this vitamin, including its chemistry, industrial preparation, biochemical systems, biogenesis, pathology and pharmacology, while E. E. Snell handles the microbiological methods of estimation and the effects of niacin deficiency in microorganisms. The final vitamin in this volume, pantothenic acid, has also been covered in outstanding fashion, the contributors being Samuel Lepkovsky, Fritz Lipmann, George M. Briggs, Floyd S. Daft, E. E. Snell, and Elaine P. Ralli.

ALVIN NASON

THE VITAMINS. *Chemistry, Physiology, Pathology. Volume III.*

Edited by W. H. Sebrell, Jr. and Robert S. Harris. Academic Press, New York. $15.00. xiv + 666 pp. ill. 1954.

This third volume completes the series on *The Vitamins*. In this final volume are given the essential information on the vitamins and growth factors not already presented. The various phases of the chemistry and biology of *p*-aminobenzoic acid are handled by Lemuel D. Wright and Peter A. Tavormina. The status of pteroylglutamic acid is given good treatment by E. L. R. Stokstad, Robert S. Harris, and Frank W. Bethell; pyridoxine (Vitamin B_6 Group) and related compounds, by John C. Kereztesy, W. W. Umbreit, Henry Sherman, E. E. Snell, Charles S. Keevil, Jr., P. György, and Klaus R. Unna; riboflavin, by Theodor Wagner-Jauregg, M. K. Horwitt, D. M. Hegsted, and E. E. Snell; thiamine, by C. P. Jansen, H. M. Wuest, Klaus R. Unna, and W. H. Sebrell, Jr.; the tocopherols, by Henry A. Mattill, Philip L. Harris, and Karl E. Mason; and new and unidentified growth factors, by Vernon H. Cheldelin. The latter include lipoic acid, carnitine, peptides, lyxoflavin, coenzyme III, factors required in unheated growth media, guinea-pig antistiffness factor,

and miscellaneous factors apparently necessary for growth, reproduction, and intermediary metabolism, although not yet purified and identified.

There is little question of the value of the 3-volume edition of *The Vitamins*. The persistently high quality of the contributions and the function of these books as a reference work for the student, teacher, and researcher, especially in view of the need for such an up-to-date source, emphasizes the worth of these volumes. On the other hand, the prohibitive price set by the publishers will undoubtedly limit its sale for the most part to college, industrial, and departmental libraries.

ALVIN NASON

PLANT PROTEINS IN CHILD FEEDING. *Medical Research Council Special Report Series, No. 279.*

By R. F. A. Dean. Her Majesty's Stationery Office, London. $2.25 (paper). viii + 164 pp. + 1 pl.; text ill. 1953.

Work with children during and after the war proved that mixtures of soya flour and malted cereals were useful as emergency rations for children. This Report is divided into 2 sections, the first of which discusses the principles of child nutrition, gives a summary of past experience, and provides also an account of some complicating factors in assessing the biological value of proteins. Part II is a description of some experiments in the use of plant preparations which were carried out in 5 German institutions in 1947–48, mainly on children aged 1 to 3 years, but also on some who were younger and others who were older. The results, although needing extension and confirmation, indicate rather clearly that soya flour and malted cereals, without milk, provide an adequate protein basis for growth in children aged 1 to 2 years; the addition of 12½% of dried skimmed milk conferred no additional benefit, but 25% of milk promoted better growth. Removal of the trypsin inhibitor from the soya is probably beneficial, although more tests are needed particularly in this regard. In children under 1 year of age the soya and malted cereal diet could be used safely up to 40 or 50 per cent of the total calories. Further work along these lines should be of very great importance in improving the diets of children in undernourished lands.

BIOPHYSICS AND GENERAL PHYSIOLOGY

BASIC MECHANISMS IN RADIOBIOLOGY. II. *Physical and Chemical Aspects. Nuclear Science Series. Division of Physical Sciences.*

Editors: John L. Magee, Martin D. Kamen, and Robert L. Platzman. National Academy of Sciences, National Research Council, Washington. $1.00 (paper). viii + 146 pp.; ill. 1953.

This lithoprinted bulletin contains an abridged transcript of the discussions at an informal conference of 23 physicists, chemists, and biologists in Highland Park, Illinois, on May 7–9, 1953. It was the third conference in a series sponsored by the National Research Council's Subcommittee on Radiobiology of the Committee on Nuclear Science. There were 5 sessions, on the following topics and with the discussion leaders indicated: Initial Energy Transfer from Incident Radiation to Matter (Robert L. Platzman); Energy Transfer from Secondary Electrons to Matter (Robert L. Platzman); Mechanisms of Energy Degradation and Chemical Change: Effects of Secondary Electrons (John L. Magee); Mechanisms of Energy Degradation and Chemical Change: Effects of Electronic Excitation (Henry Linschitz); Summary: Importance of Radiation Chemical Effects in Radiobiology (Martin Kamen). Collections of references and a full index are included.

What the records of such meetings as the radiobiology conference lack in formal and careful scrutiny and in considered expression, they gain by permitting freedom of speculation and the subjection of opinions to immediate, vigorous question and debate. The value of such records is therefore great in the immediate context, and may prove highly stimulating to those who were unable to attend; but the permanent value is most likely a great deal less than that of more conventional papers and reviews. It is consequently distinctly worth emphasizing that quick and inexpensive publication of such records is imperative. Here the National Research Council indeed shows the way. While the content is very like the numerous Conference Reports of the Macy Foundation, this format is cheaper and quicker to publish; and the bulletin does not, like so many similar reports, lack an index.

BENTLEY GLASS

BIOCHEMISTRY

CHEMISTRY OF THE SOIL. *American Chemical Society Monograph No. 126.*

Edited by Firman E. Bear. Reinhold Publishing Corporation, New York. $8.75. x + 373 pp.; ill. 1955.

Following an excellent introduction by the editor, important topics such as soil development, chemical composition of soils, exchange phenomena, soil organic matter, oxidation-reduction processes, and trace elements are discussed rather unevenly by 12 different authors. Consideration is given to the recent concepts of the nature of clays and soil minerals. The final chapter is a stimulating discussion of soil chemistry and plant nutrition. Methods of soil analysis are given in an Appendix.

While a bibliography follows each chapter, in the text one misses direct references to the work of individuals. The book deals with upland, temperate-zone soil conditions. The important subject of tropical, and especially padi (rice), soils is hardly touched upon. There is an uncritical acceptance of traditional and unfortunately inadequate views as to the chemical characteristics of certain of the "great soil groups."

ROBERT L. PENDLETON

ELECTROCHEMISTRY IN BIOLOGY AND MEDICINE. *The Electrochemical Society Series.*

Edited by Theodore Shedlovsky. John Wiley & Sons, New York; Chapman & Hall, London. $10.50. xii + 369 pp.; ill. 1955.

This book contains the papers presented at a symposium sponsored by the Electrochemical Society in New York in April, 1953. The contents of the volume can be judged by the following abbreviated titles of the contributions: Introduction (Shedlovsky); Donnan Potentials (Hitchcock); Porous Membranes (Sollner); Membranes of High Electrochemical Activity (Sollner, Dray, Grim, Neihof); Dynamic Negative Admittance in Membranes (O. Schmitt); Nerve Impulse (Cole); Potentials of Bioelectric Tissues (Grundfest); Acetylcholine-Esterase-Acetylase (Nachmansohn, Wilson); Electrical Properties of Plant Cells (Blinks); Violations of All-or-None Law re K^+ in Protoplasm (Osterhout); Diffusion in Liquids (Longworth); H^+ Titration Curves of Proteins (Tanford); Ion Activity of Proteins with Collodion Membranes (Carr); Activity Coefficients of Some Na and K Phosphates (Snell); Polarography of Plasma Proteins (Müller); Electrocardiography (Johnston, Cordes); EEG Localization of Brain Tumors (Bagchi); and Electric Signs of Epilepsy (Jasper).

The contributions cover a wide range of fields of interest, and the book is therefore probably of more interest to the non-specialist than to the research worker in any of the particular fields represented. Three of the contributions have been previously published in *Ion Transport Across Membranes* (H. T. Clarke, ed.).

L. J. MULLINS

BIOLOGIE UND WIRKUNG DER FERMENTE. *4. Colloquium der Gesellschaft für physiologische Chemie, am 17/18. April 1953 in Mosbach-Baden.*

Springer-Verlag, Berlin, Gottingen, and Heidelberg. DM 19.60 (paper). viii + 176 pp. + 1 chart; ill. 1953.

This slim, paper-bound book contains the 8 papers, and discussions thereof, presented at a meeting of the Gesellschaft für physiologische Chemie. Appropriately enough, considering the title of the symposium: Biology and Action of Enzymes, the published proceedings are dedicated to Otto Warburg on his 70th birthday.

The titles and authors of the papers are as follows: The Biology of Enzymes (Konrad Lang); Proteins as Carriers of Enzyme Activity (Theodor Bücher); Structurally-Bound Enzymes (E. C. Slater); Enzyme Chains and their Importance in the Regulation of Carbohydrate Metabolism (Helmut Holzer); Antagonisms and Competitions for a Place on the Enzyme (J. Kühnau); Activation and Chemical Specificity of the Digestive Endopeptidases (P. Desnuelle and M. Rovery); The Mode of Operation of Dehydrogenases with Special Reference to Alcohol Dehydrogenase (Roger Bonnichsen); and Group Transfer by Enzymes Acting on Carbohydrates (Kurt Wallenfels). With the exception of the papers by Slater and by Bonnichsen, which are in English, the texts of all the papers and the discussions are in German.

These papers may be classified as general review articles. Biologists probably will be interested only in the first two listed above. Lang has collected data from many sources on the distribution of enzymes in various tissues of animal origin; he also discusses the known effects of a number of environmental factors on the enzyme activity of cells, and the mechanism and site of enzyme synthesis. Bücher's paper summarizes the evidence to show that the catalytic activity of a holenzyme resides in the protein (apoenzyme) and that the coenzyme must be considered, together with the substrate, as a partner in the enzymatic process. The other papers are of a more highly specialized nature, and will be of particular interest only to the enzyme chemist.

SOFIA SIMMONDS

ADVANCES IN ENZYMOLOGY *and Related Subjects of Biochemistry. Volume XVI.*

Edited by F. F. Nord. Interscience Publishers, New York and London. $11.00. vi + 584 pp.; ill. 1955.

Surely, the many review volumes published annually in this country must rival, in number and diversity of subject matter, the chemical elements in the Periodic Table. Yet each new volume issued contains at least one article of special interest to some biologist. The latest addition (Volume 16) to the series *Advances in Enzymology and Related Subjects of Biochemistry* is no exception.

Among the 8 articles in this volume, there are at least 2 of general interest to the biologist. The long review on The Chemistry of the Cell Nucleus (by V. C. Allfrey, A. E. Mirsky, and H. Stern) describes the exciting developments in this field during the last decade. Particular attention should be directed to the authors' critical survey of the experimental procedures used in the study of these cell constituents. A second, long article (by H. S. Mason) is devoted to the Comparative Biochemistry of the Phenolase Complex; that is, to the

enzyme systems operative in the 2-step conversion of mono-phenols to quinones, a process of importance in the biosynthesis of a variety of plant products, in the formation of arthropod cuticles, and in the pigmentation (melanin formation) of many tissues in chordates.

The attention of the physiologist will probably be attracted by W. H. Seegers' long review on the Coagulation of Blood, which discusses the many factors involved in the conversion of prothrombin to thrombin, the role of the latter in the formation of fibrin from fibrinogen, and the action of antithrombin and of certain inhibitors in the clotting process. Under the heading of physiology may also be included the article by A. G. Szent-Györgyi entitled Structural and Functional Aspects of Myosin. Here, the main emphasis has been placed on the molecular organization of myosin and on those of its properties relating to its biological functions.

The remaining reviews probably should be classified as biochemical and deal with coenzyme A structure (J. Baddiley), beta-glucuronidase (W. H. Fishman), transamination (A. Meister), and intermediates in amino acid biosynthesis (B. D. Davis). The section on coenzyme A is short, but it includes a brief discussion of the biosynthesis and function of the coenzyme in addition to a descriptive summary of the determination of its structure. The comprehensive review on beta-glucuronidase covers all aspects of its chemistry and physiology, and describes also its use in steroid biochemistry. Meister's discussion of transamination in animals, plants, and microorganisms is certainly the best review of this subject to date, and should prove an invaluable aid to anyone interested in this important biological reaction. The section on intermediates in amino acid biosynthesis is too short to do justice to the enormous mass of data that has been accumulated in recent years. Davis has attempted to restrict the discussion to intermediates arising during the formation of the carbon skeletons of protein amino acids from carbohydrate precursors. Consequently, most of the results cited are drawn from experiments on microorganisms, although reference is made to analogous experiments with mammalian systems. It is, perhaps unfortunate that this topic was chosen for a review to be published in the same year as the superb Johns Hopkins Symposium Volume on *Amino Acid Metabolism*.

All the articles in *Advances of Enzymology* have some literature references bearing a 1954 dateline. In my own opinion, it would be helpful to the reader who turns to this volume as the first step in a literature survey if each review also carried a date of submission.

SOFIA SIMMONDS

THE CHEMISTRY OF LIPIDS OF BIOCHEMICAL SIGNIFICANCE. *By J. A. Lovern. John Wiley & Sons, New York; Methuen & Company, London.* $1.75. xiv + 132 pp.; ill. 1955.

This small reference book on the biochemistry of lipids is another of the excellent Methuen series of monographs on biochemical subjects. Admittedly limited in scope, it nevertheless gives a fairly complete over-all picture of lipid chemistry. The following topics are covered: structure, preparation, and analysis of lipids; the state of lipids in the tissues; and finally the possible function of lipids in living organisms. The biochemistry of the carotenoids and fat-soluble vitamins has not been included.

This work is especially to be recommended to the student or research worker who by virtue of training or interest has had only a slight acquaintance with lipid chemistry. For those who wish to delve more deeply into the field, extensive literature references are provided at the end of each chapter. Finally, it provides an excellent introduction to some of the more exhaustive treatises on the subject by Bloor and Deuel.

I. R. LEHMAN

INTRODUCTION TO PHYSIOLOGICAL AND PATHOLOGICAL CHEMISTRY. *Fourth Edition. By L. Earle Arnow; revised with the assistance of Marie O. D'Andrea. The C. V. Mosby Company, St. Louis.* $3.75. 508 pp.; ill. 1953.

This comprehensive textbook for the instruction of nurses differs from the foregoing edition (*Q.R.B.*, 25: 246. 1950) in the inclusion of 3 new chapters which current developments in the need for disaster nursing, blood transfusions, and general chemical knowledge would appear to warrant. These chapters are respectively on the subjects The Periodic Table and Some Important Elements, Nuclear Chemistry and Atomic Energy, and The Blood. Since these chapters range in length from 12 to 23 pages, it is obvious that they must survey those subjects lightly. There has been a definite effort throughout to keep the text abreast of recent developments, but the devotion of half a page, for example, to Vitamin B_{12} and one page to all antibiotics together impresses one with the superficiality of physiological and biochemical knowledge which is considered to be sufficient for nurses.

ADVANCES IN CARBOHYDRATE CHEMISTRY. *Volume 8. Edited by Claude S. Hudson and Melville L. Wolfrom; associate editors for the British Isles, Stanley Peat, Maurice Stacey, and E. L. Hirst. Academic Press, New York.* $10.00. xvii + 408 pp. + 1 pl.; text ill. 1953.

The *Advances* flow in a mighty stream from the presses, and if sometimes they remind one of the inches of gain

reported in the bitter trench fighting of the First World War, in general they evoke more appropriately the fluid skirmishes of the Armored Divisions in World War II. This volume is dedicated to Claude S. Hudson, leader in carbohydrate chemistry, whose death in 1952 not only deprived the field of a notable pioneer but also of one whose editorial services to the *Advances in Carbohydrate Chemistry* had been outstanding since the series was founded in 1944. His standards were exacting, and both in scientific quality and in writing he held contributors to his own level. This volume bears the marks of his labor and it will be the last to do so. Let us hope that his successors will maintain the level that has been set.

The contributions in this volume are as follows: Relative Reactivities of Hydroxyl Groups of Carbohydrates (James M. Sugihara); The Chemistry of the 2-Desoxysugars (W. G. Overend and M. Stacey); Sulfonic Esters of Carbohydrates (R. Stuart Tipson); The Methyl Ethers of D-Mannose (G. O. Aspinall); The Chemical Synthesis of D-Glucuronic Acid (C. L. Mehltretter); D-Glucuronic Acid in Metabolism (H. G. Bray); The Substituted-Sucrose Structure of Melezitose (Edward J. Hehre); Composition of Cane Juice and Cane Final Molasses (W. W. Binkley and M. L. Wolfrom); and Seaweed Polysaccharides (T. Mori). The reviews relating to the 2-desoxysugars, including of course desoxyribose, to D-glucuronic acid, to melezitose, and to the polysaccharides of agar and other seaweed products will have particularly wide value for biochemists and biologists who are not carbohydrate specialists.

BIOCHEMISTRY OF THE AMINOSUGARS.

By P. W. Kent and M. W. Whitehouse. Academic Press, New York; Butterworths Scientific Publications, London. $6.80. x + 311 pp. + 1 pl.; text ill. 1955.

This book is the first comprehensive survey of the subject since Levene's classic work of 30 years ago. It is divided into two general parts, biochemistry and chemistry of the amino sugars. The occurrence and composition of aminopolysaccharides of various tissues and organs, and the enzymes catalyzing their hydrolysis are discussed in detail. The chemical reactions by which the various components of the aminopolysaccharides can be identified are considered with authority, and the intelligent use of extensive references reveals the authors' familiarity with their subject.

The chemical aspect of the amino sugars is treated in somewhat greater detail than the biochemistry, and this is probably not entirely due to the lack of information. For instance, the tables on the occurrence of enzymes could be more complete, and data on the tissue occurrence of such an important enzyme as hyaluronidase would have made a very valuable table.

Aside from these minor points the book is clearly written, carefully edited, and remarkably free of typographical, grammatical, and spelling errors (only one misspelled word, which could not be an anglicism, was found in the entire book). Mann of the references were checked and found accurate.

This book will be an invaluable aid to all who are concerned with problems relating to hyaluronic acids, chondroitin sulfates, blood group substances, mucins, and mucoproteins.

SAMUEL P. BESSMAN

BRANCHED MOLECULES. *Ann. N. Y. Acad. Sci., Vol. 57, Art. 4.*

Edited by Roy Waldo Minor; consulting editor, Frederick R. Eirich; 19 contributors. New York Academy of Sciences, New York. $3.50 (paper). Pp. 325–450; ill. 1953.

This is the collection of 11 papers given at a Conference on Branched Molecules held in January, 1953. The contents are as follows: Introduction to Branched Molecules (H. Mark); Physical Properties of Solutions of Branched Polymers (B. H. Zimm); Dilute Solutions of Branched Polymers (W. H. Stockmayer & M. Fixman); Application of Viscosity Methods to the Study of Branching in Polysaccharides (M. Wales, P. A. Marshall, S. Rothman, & S. G. Weissberg); Relation between Degree of Branching and Degree of Conversion During Polymerization (O. L. Wheeler); Crosslinking in Monovinyl Monomers. I. By Chain Transfer with the Polymer Chain (T. G. Fox & S. Gratch); The Structure of Amylopectin and Glycogen (C. O. Beckmann); Branching in Polyethylene (F. M. Rugg, J. J. Smith, & L. H. Wartman); Studies on Polyvinyl Chloride II. Branching (J. D. Cotman, Jr.); Branching in Dienes (M. Morton); and Branching by Long Chain Substituents (H. Mark).

Like so many of the interesting symposia of the New Academy of Sciences, the usefulness of this publication is greatly reduced by its lack of any sort of index.

MICROBIOLOGY

GENERAL MICROBIOLOGY.

By William G. Walter and Richard H. McBee; based on the original text by D. B. Swingle. D. Van Nostrand Company, New York, Toronto, and London. $4.75. viii + 345 pp. + 1 pl.; text ill. 1955.

This is a revision of a work of the same title by D. B. Swingle which was published in 1940 and again in 1947. The revision seems to have been carefully done, and no misprints were noted. The interpretations are intelligent, and despite a fairly careful search there seemed to be none of the outdated and tiresome misconceptions which are commonly "parroted" from one textbook to

another. As an elementary textbook, with considerable stress on the industrial as well as the sanitary aspects of microbiology, the work merits careful attention.

WALTER C. TOBIE

PRINCIPLES OF MICROBIOLOGY. *Second Edition.*

By Charles F. Carter and Alice L. Smith. The C. V. Mosby Company, St. Louis. $5.00. 604 pp.; ill. 1954.

This is a revision and enlargement of the first edition (*Q.R.B.*, 27: 120. 1952). Considering the expansion in size, the price is reasonable. As before, the textbook provides an excellent general survey of microbiology, with stress on medical aspects. The commercial applications of microorganisms are not always made entirely clear. Thus, in the treatment of alcoholic fermentation (p. 135), the student might get the idea that the fermentation of molasses was an obsolete process and that alcohol was produced more or less directly from cellulose. Considering that BCG vaccine has been moderately effective in protection against tubercular infections, the statement that "attempts to produce an artificial immunity have met with little success" (p. 325) requires modification. On the other hand, the section on antibiotics, though brief, is up to date and quite adequate for an elementary textbook. In general, the book can be recommended.

WALTER C. TOBIE

TEXTBOOK OF BACTERIOLOGY. *Third Edition.*

By Joseph M. Dougherty and Anthony J. Lamberti. The C. V. Mosby Company, St. Louis. $8.25. 598 pp.; ill. 1954.

The second edition of this textbook was reviewed in 1952 (*Q.R.B.* 27: 120). As before, it is essentially a textbook for premedical or predental students with stress on pathogenic microbiology; but 5 new chapters on non-medical aspects have been added, to somewhat broaden its scope. Instead of footnotes, references are now given at the end of each chapter. Former inaccurate statements about typhus have been amended, but "tetany" is still used as a synonym for tetanus. In the section on antibiotics too much stress is possibly laid on compounds of merely academic interest, such as bacillin and erythromycin, whereas no mention at all is made of the close relationship between aureomycin and terramycin. Neither is it a valid generalization to say that "glucose agar is the medium of choice for chromogenic bacteria" (p. 127). Owing to its rather loose organization and frequent vagueness of statement, this book is still (like the second edition) only fairly good, and not up to the best standards.

WALTER C. TOBIE

PAUL EHRLICH CENTENNIAL. *Ann. N. Y. Acad. Sci., Vol. 59, Art. 2.*

Edited by Roy Waldo Miner; consulting editor, E. Grunberg; conference chairmen, Robert J. Schnitzer and E. Grunberg; 11 other scientists. The New York Academy of Sciences, New York. $3.00 (paper). Pp. 141–276 + 1 pl.; text ill. 1954.

Among the original papers given at this conference were the following: Paul Ehrlich's Influence on Chemistry and Biochemistry (Hugo Bauer); Ehrlich's Side-Chain Theory in the Light of Present Immunology (Ernest Witebsky); Ehrlich and Problems of Immunity (Bela Schick); Paul Ehrlich and the Cancer Problem (C. P. Rhoads); Chemotherapy of Trypanosome Infections (C. H. Browning), Chemotherapy of Spirochetal Infections (John A. Kolmer); Chemotherapy of Bacterial Infections (Robert J. Schnitzer); Drug Resistance (Harry Eagle); Vital Staining (N. Chandler Foot); and Blood Morphology (Paul Reznikoff). These papers are accompanied by useful sets of references.

The contributions are of uniformly high quality. The publication should be of great value to those who wish interpretations of Ehrlich's theories in the light of present biochemical knowledge.

WALTER C. TOBIE

PERSPECTIVES AND HORIZONS IN MICROBIOLOGY. *A Symposium.*

Edited by Selman A. Waksman. Rutgers University Press, New Brunswick. $3.50. x + 220 pp. + 2 pl.; text ill. 1955.

This is a symposium given at the dedication of the Institute of Microbiology at Rutgers University on June 7, 1954. The original reviews and discussions (as distinguished from general addresses) are: The Microbe as a Whole (C. B. Van Niel); Aspects of Metapoietic Integrations (André Lwoff); Genetics and Microbiology (Joshua Lederberg); Nutritional and Enzymatic Studies on Microbial Mutants (Bernard D. Davis); Bacterial Metabolism (H. A. Barker); Molds as Metabolic Models (Jackson W. Foster); Metabolic Pathways (W. W. Umbreit); Pathways in Biological Nitrogen fixation (Perry Wilson); Microorganisms and Steroid Transformations (Durey H. Peterson); Unsolved Problems in Immunology (M. Heidelberger); Inhibition of Virus Reproduction by Chemical Substances (F. L. Horsfall, Jr.); Problems in Antibiotic Research (Harry Eagle); and Microorganisms and Plant Life (Robert L. Starkey). References are given.

The quality of the papers is extremely high, and they well merit the attention of those interested in the topics discussed.

WALTER C. TOBIE

HANDBOOK OF PRACTICAL BACTERIOLOGY. *A Guide to Bacteriological Laboratory Work. Ninth Edition.*

By T. J. Mackie and J. E. McCartney. E. & S. Livingstone, Edinburgh and London; [The Williams & Wilkins Company, Baltimore.]. $5.50. viii + 677 pp. 1953.

This volume is exactly what the title says. It is a concise, highly practical presentation of the field of bacteriology for the student as well as for the worker in the field of diagnostic bacteriology. The chapters on bacteriological technic, including microscopy, culture media, animal experimentation, etc., are particularly good. However, the statement that media made from meat infusions are better than those made from chemically defined peptones is open to question.

A tremendous amount of material is covered in the last part of the book, on Bacteriological Diagnosis. The sections on viruses, rickettsia, pathogenic fungi, and blood parasites are very brief and limited. On the whole, the material is up to date for the year of publication. The index is adequate. As a whole, the book would appear to be quite usable for bacteriological technic and diagnosis, but not adequate for methods relating to viruses, rickettsia, fungi, or blood parasites.

ELIZABETH PETRAN

TRAVAUX PRATIQUES DE BACTÉRIOLOGIE.

By Henri Bonnet and Armand Névot. Masson & Cie., Paris. 960 fr. (paper). viii + 210 pp. + 6 pl.; text ill. 1955.

This is mainly a laboratory handbook for the identification of some 30 bacteria (and spirochetes), mostly pathogenic, presented from a relatively elementary point of view. From the standpoint of microbiology little of outstanding interest is included. Since the work is excellently printed, as well as inexpensive, it should be of value to bacteriologists who wish to improve their reading knowledge of French. It could be used as a classroom textbook.

WALTER C. TOBIE

AN INTRODUCTION TO THE BIOLOGY OF YEASTS.

By M. Ingram. Pitman Publishing Corporation, New York, Toronto, and London. $5.00. xiv + 273 pp. + 12 pl. + 1 folded chart; text ill. 1955.

This book is written in a very logical fashion. It deals first with the general appearance and composition of the yeasts, then with their biochemical properties, and concludes with a consideration of growth and reproduction. The author states in the Preface that his primary emphasis is on the physiology and biochemistry of the yeasts, for he feels that their morphology and genetics are adequately covered elsewhere. The purpose of the book is to make available to the reader in one convenient place a variety of knowledge about "what the yeasts are and what they do."

In my own opinion, the author has set himself a difficult task and has, by and large, acquitted himself rather well. He has succeeded especially well in presenting a variety of information on the biochemistry of yeast, much of which is quite up to date. In order to keep the book within reasonable size limits, he has had to restrict discussion in many places, but has succeeded in presenting a fairly balanced picture of yeast biochemistry.

The author has been less successful in his treatment of yeast genetics and cytology. For example, he states that it is not certain at present which structure in yeast is the nucleus, and yet on the same page, he makes the statement that "fusion of nuclear structures has been observed in conjugating cells." He is also on questionable ground in his statement (Plate V, d), that the first bud after conjugation always appears asymmetrically. I have myself often observed first buds arising from the center of the conjugation bridge, and there are numerous photographs in the literature to show symmetrical bud formation (for example, in Lindegren's book, 1951). Ingram's statement that the mating type mutates frequently [p. 205] should be qualified so as to make it clear that this is not true for all strains of yeast studied.

The general appearance and style of the book are good. I observed only three typographical errors. An incomplete sentence on p. 229, dealing with the drying with silica, appears to be the result of a typesetter's omission.

The book has definite merit as a compilation of a variety of information about the yeasts, especially their biochemistry and physiology. As a study of the over-all "biology" of the yeasts, it is somewhat weak in certain areas of genetics, but is highly informative in regard to the ecology, growth, and general consideration of the yeasts as living, functional organisms. As such, it will be of value to the student in microbiology. It is to be hoped that in subsequent editions, the author will be able to strengthen the few weak points in the book so as to make it uniformly commendable.

SEYMOUR POMPER

PARASITOLOGY

INTRODUCTION TO PARASITOLOGY. *A Laboratory Manual.*

By the late Philip A. Hawkins, William D. Lindquist, and Irving P. DeLappe. Burgess Publishing Company, Minneapolis. $2.75 (paper). vi + 122 pp. + 46 pl. 1953.

The authors of this laboratory manual are on the staff of Michigan State University, and the manual deals

with the material covered in an introductory course covering one term of two lectures and two laboratory periods per week. The arrangement of parasites is by phyla rather than by host, and progresses from the arthropods through the worms to the protozoa. Emphasis is on systematics, correlated life histories, and structure. The text is clear, the descriptions adequate for beginners, and labelled drawings eliminate the need for art work on the part of the student. The latter is both an advantage and a disadvantage, and care must be exercised that a labelled drawing not be utilized as a subterfuge for a competent laboratory instructor.

HEALTH AND DISEASE

WATER SUPPLY AND WASTE-WATER DISPOSAL.
By Gordon Maskew Fair, John Charles Geyer, and John Carrell Morris. John Wiley & Sons, New York; Chapman & Hall, London. $15.00. xii + 974 pp. + 1 chart; ill. 1954.

Comparatively few biologists are professionally associated with municipal and industrial water supply and waste disposal planning and operation. Many biologists, on the other hand, are asked for advice on problems in these fields. On the whole, we are poorly prepared to give useful service because we do not appreciate the requirements and magnitudes of waterworks and waste-disposal plant practice. It is interesting to examine this most recent and most extensive engineering textbook to discover what biological phenomena specialists in sanitary engineering regard as important, and how they solve their problems. A search through this book will demonstrate that biological limits to practice are numerous and pervasive, that their day-to-day control is fairly good, and that they have not been carefully or extensively studied.

Very few biologists would willingly assume responsibility for control of the large number of factors that determine satisfactory water treatment and waste disposal, and none would claim authoritative stature in the diverse zoological, botanical, bacteriological, ecological, and biochemical systems that are involved. This requires a special sort of innocence. The solutions have in fact been derived empirically, and they are presented in that fashion in this text.

The net effect is a "once over lightly" discussion of such varying problems as the history, current status, and ecology of water-borne disease; the biological processes of self-purification; the natural history and physiology of clogging, sliming, and nuisance organisms; the relation of plankton and weeds to water quality; the biochemistry of disinfection by chlorine and other materials and methods; conservation practice and watershed control; physical-chemical limnology of impoundments; odors and tastes; the sanitation of swimming pools; biological societies and processes on waste trickling filters, activated sludge systems, and sludge digesters. The problems are clearly stated, the present practices outlined and justified.

The text is intended for teaching engineering design. Principles are illustrated by the quantitative solution of type problems. The book is also intended to serve as a reference work for practicing engineers. Three sections have reference value for biologists working in the water and waste field. Chapter 18, Elements of Water Chemistry, is a very well-organized description of chemical equilibria in natural waters, of solubility limits, *p*H, and redox systems. Chapter 27, Disinfection, Destruction of Aquatic Growths, and Removal of Odors and Tastes, brings together and clarifies much of the scattered literature on chlorine disinfection and the mechanism of chlorine action. Chapter 28, The Natural or Self Purification of Water, gives in some detail the design methods now in use by sanitary engineers for determining the concentrations of domestic waste that may be admitted to streams of various types. The coliform die-away and oxygen sag limits have become dogmas in some sections of the profession. Stream biologists may disagree with these limits, especially with their application to industrial wastes, but they should know the background that sanitary engineers now accept.

The first three chapters, an elementary description of common water-supply and waste-treatment systems, and of the problems involved in securing an adequate, safe supply, is a useful introduction to the problems of municipal supply. Chapters 6 to 12, which include methods for estimating water requirements, yield, and storage, together with discussions of applied meteorology and geology, will be valuable to biologists interested in conservation requirements for our increasing population and industry. These sections, more than the structural design material that follows, give bases for evaluating the future trends in water resource policies.

CHARLES E. RENN

FIRST INTERNATIONAL SYMPOSIUM ON YAWS CONTROL. *World Hlth. Org. Monogr. Ser., No. 15.*
World Health Organization, Genève; [Columbia University Press, New York]. $4.50 (paper). ii + 419 pp.; ill. 1953.

Few tropical diseases are more disfiguring and have attracted greater attention than yaws, the non-venereal infectious disease caused by *Treponema pertenue*. During the past decade two major advances have been directed at the eradication of yaws: the one, the development of Ehrlich's hoped-for single-injection cure in penicillin; the other, the advent of international health work under the World Health Organization. This symposium takes stock of the success of the measures which have been undertaken and plans for new efforts. It was held in Bangkok in March, 1952, with over 70 participants.

Eighteen papers were presented on the Biology of Yaws, Antibiotics in the Treatment of Yaws, the Extent and Nature of the Yaws Problem; the Development of Plans of Operation, the Demonstration, Survey, and Planning Phase; The Expansion Phase; The Consolidation Phase; and The Role of International Organizations. The success of so well-planned an attack on a particular disease may be predicted. The progress made during the next few years should be spectacular and will be watched with world-wide interest.

PATHOLOGY.

By Peter A. Herbut. Lea & Febiger, Philadelphia. $16.00. 1227 pp. + 6 pl.; text ill. 1955.

This new textbook of pathology, written by the Professor of Pathology at Jefferson Medical College, covers the subject adequately, but adds little to the already numerous texts on this subject. One novelty is a chapter on autopsy procedure, including normal weights and measurements. There is also a short chapter on the history of pathology, but I believe an historical survey of important diseases given with the description of the specific disease makes a more graphic picture for the student. There are 5 additional preliminary chapters outlining the main types of disease processes—congenital anomalies, degenerations, inflammations, physical and chemical disturbances, and tumors. The remaining 33 chapters are devoted to organology, with a review of pathological processes in the above sequence.

The main fault of this book is due to the attempt to cover an encyclopedic volume of material by overcondensing important subjects. Pathologic conditions are defined rather than described, and the lack of critical descriptions and evaluations is a serious defect. For example, the 15 words devoted to lead encephalopathy hardly provide a graphic description of this condition. Furthermore, important lesions are omitted and systemic correlations of diseases are inadequate. As examples, I might list the omission of the almost pathognomonic periarterial fibrosis of the spleen in systemic lupus and the omission of the interesting Marfan's syndrome. Clinical correlations are often inadequate. For instance, although every aspect of tuberculosis and every term applied to it is defined, there is no complete pathologic picture with clinical correlation. Another fault caused by the uncritical inclusion of too much material is a dogmatic presentation precluding a thorough survey of the subject and its etiologic possibilities. Hodgkin's disease is dismissed as a neoplasm, although many pathologists consider it to be of unknown etiology; all inclusions are said to be indicative of viral infection, although lead and other heavy metals may produce similar lesions; and though Herbut gives overuse as a cause of atrophy, I think this concept is open to discussion.

Each chapter is appended with an adequate bibliography. One outstanding contribution comprises the remarkably excellent illustrations of gross and microscopic changes. These illustrations are so complete as to form a virtual atlas of pathology. They give a more complete survey of pathological lesions than I have seen in any other textbook upon this subject.

ELLA H. OPPENHEIMER

PEPTIC ULCER.

By C. F. W. Illingworth. E. & S. Livingstone, Edinburgh and London; [The Williams & Wilkins Company, Baltimore.] $8.50. viii + 287 pp.; ill. 1953.

The author says in his Preface: "Peptic ulcer is a common disease, painful, incapacitating and not free from danger." This is to put it mildly, since not only those who have peptic ulcers worry about getting rid of them, but also those who have yet to acquire one worry about the likelihood of their doing so. The subject of gastric and duodenal ulcers is discussed by the Regius Professor of Surgery of the University of Glasgow in a thorough survey of almost all imaginable relations except that of differential incidence among the ABO blood groups (which is not fictional). Much of the original data is cited, and each chapter is followed by references. Color illustrations as well as half-tones are abundant. There is an index. In short, this is an excellent textbook and reference work on the subject.

THE MECHANISM OF INFLAMMATION. *An International Symposium.*

Edited by G. Jasmin and A. Robert. ACTA, Montreal. $8.50. 308 pp.; ill. 1953.

During the 19th International Congress of Physiology, held in Montreal August 31–September 4, 1953, a symposium was held on the mechanism of inflammation, the first on that subject, it is believed, to be held anywhere. It was wire-recorded in its entirety, and the present very prompt publication was the result. The formal papers were not read but the proofs of the papers were distributed three weeks in advance. The time allotted for the symposium was thus saved almost entirely for discussion. Each participant was assigned the task of introducing the discussion of one particular communication; and time for free discussion was allotted at the end of the meeting. This plan seems to have been a thorough success. Twenty-four papers were grouped under the headings of Generalities; Morphology; Chemistry; and Hyperergic Inflammations (Histamine, Antihistamines, etc.). The volume is supplied with both an Author Index and also a Subject Index, the latter very full and based on a novel principle that permits the indication of stimuli and target organs in each case. This is undoubtedly one of the most interesting sym-

posium volumes yet to be published, and others of the same kind, of which there is such a number nowadays, might well adopt at least some of the methods used in this one.

Of the substance, it is sufficient to say that a notable group comprising most of the well-known physiologists and biochemists who have been associated with the study of inflammation was assembled.

CEREBRAL PALSY. *Its Individual & Community Problems.*

Edited by William M. Cruickshank and George M. Raus. Syracuse University Press, Syracuse. $7.50. xvi + 560 pp. + 12 pl.; text ill. 1955.

A vast amount of interest, money, and labor have gone into the problem of cerebral palsy over the past decade. This book, written by a group of experts in the handling of cerebral palsy patients, gives an over-all view of the results of this effort and an idea of the advances to be expected of future activities of this nature.

The introductory chapter by the editors shows the confusion present among clinicians as to the incidence of the disease and attempts to make the category of "cerebral palsy" embrace practically the entire gamut of congenital and neonatal disorders of the central nervous system. The second chapter, entitled Medical Aspects, attempts to prove by reiteration that the primary cause of cerebral palsy is some form of anoxia, although the best evidence that it cites refutes this claim.

A number of misleading and occasionally erroneous statements are made, such as that histiotoxic [sic] anoxia is a cause of anoxemia (p. 30), and that in kernicterus "excess bilirubin stains the basal nuclei as a result of hemolysis" (p. 39). Many of the figures in this chapter are either illegible because they are large charts scaled down photographically, or are uncommunicative and contribute no clarification to the text.

The chapters on evaluation of intelligence and on mental retardation in the cerebral palsied child are of particular interest because they present in a rational manner the evidence for the growing awareness that patients with cerebral palsy are generally mentally retarded to an extent which exceeds the possibility that they are not being tested fairly. About half of the book is devoted to a description of practical methods for evaluating the extent of the disease, for teaching the patient to speak, read, write, and perform to the best of his ability, and for helping parents to adjust to their problem. This is the major contribution of this volume and is presented in detail with illustration and case histories. It should be of great help to those who are charged with these problems.

The book would profit from some careful editing, since it is replete with spelling and grammatical errors, averaging at least one of the latter to a page.

SAMUEL P. BESSMAN

PITUITARY CHROMOPHOBE ADENOMAS. *Neurology, Metabolism, Therapy.*

By John I. Nurnberger and Saul R. Korey. Springer Publishing Company, New York. $7.00. x + 282 pp.; ill. 1953.

This book discusses first the Anatomy of the Pituitary and the Functional Anatomy of the Perisellar Region, and the Metabolism of the pituitary hormones. The remaining chapters are headed: The Material and Initial Symptoms; Neurologic Signs and Symptoms; Metabolic Symptomatology; Additional Laboratory Data and Differential Diagnosis; Pathology; and Therapy. The book is based on the metabolic, endocrine, ophthalmological, and therapeutic studies of 117 patients with pituitary chromophobe adenomas. The senior author is a cellular neurologist and the junior author a biochemist, and their different viewpoints and training combine to yield a thorough clinical approach.

THE PSYCHOLOGICAL VARIABLES IN HUMAN CANCER. *A Symposium Presented at the Veterans Administration Hospital, Long Beach, California, October 23, 1953.*

Edited by Joseph A. Gengerelli and Frank J. Kirkner. University of California Press, Berkeley and Los Angeles. $3.00. vi + 135 pp.; ill. 1954.

The participants in this symposium were surgeons, psychologists, internists, psychiatrists, one biophysicist, and others. The study carried out and reported was stimulated by the observations common to those working in the field of clinical cancer that frequently when cancer develops in a patient who is intelligent, has a fine personality, and is a "prince of a fellow," the course of the disease is rapidly downhill, the cancer spreading widely throughout the local lymphatics and to the distant parts of the body. On the other hand, the indolent, uneducated patient, the down-and-outer, may live many years with his cancer.

Observations of the psychological reactions of patients with cancer suggest a relationship of rate of growth to activity of the sympathetic and autonomic nervous systems. The endocrine glands have an important role in this relationship. It is pointed out that in patients with fast-growing cancers there is defensiveness, anxiety and inhibitions, whereas when the cancer is slow-growing there is no defensiveness, there is minimal anxiety and few inhibitions.

Psychological tests such as the Minnesota Multiphasic Personality Inventory, Wechsler-Bellevue, and Rorschach tests were used in determining the presence

of anxiety defensiveness and inhibitions. Host-resistance and host-acquiescence are discussed at length.

Are the psychological reactions coincidental with cancer growth, or is there a causal relationship? Are we studying cancer growth in already established personalities? To understand thoroughly the results of this study one must evaluate psychological instruments. All the patients who were studied were told they had malignant disease. One wonders what reactions would be discovered when studying patients who had cancer, but did not know the nature of their illness.

This study is a worthwhile and commendable one and should provoke further investigation into the psychological and psychiatric reactions in patients with cancer, as well as the relations of the endocrine glands and the autonomic and sympathetic nervous symptoms to growth in general, both benign and malignant.

GRANT E. WARD

MANUAL OF PSYCHOLOGICAL MEDICINE. *For Practitioners and Students. Third Edition.*

By A. F. Tredgold and R. F. Tredgold. Baillière, Tindall and Cox, London; [The Williams & Wilkins Company, Baltimore]. $7.00. xii + 328 pp. 1953.

This book, by an English physician of University College Hospital, London, was first written in 1943. This 3rd edition was largely prepared by the senior author's son during the period of the father's failing sight and health, shortly before his death in 1952. The stand is taken that most mental disorder and mental defect are hereditary in causation or predisposition, but there is practically no consideration of the more recent data bearing on that conclusion. The illuminating studies by Kallmann and others on the concordance of mental disorders in twins are not mentioned, although Penrose's book, *The Biology of Mental Defect*, has been consulted. The approach to the subject is that of classification. After introductory chapters on the normal mind, nomenclature and classification of mental abnormalities and the problems of causation and symptomatology, there follow in succession chapters on Mental Instability, Anxiety States, Hysteria, Obsessional Neurosis, Neurasthenia, Neuroses of Mixed Types, Epilepsy, Manic-Depressive Psychosis, Mania and Melancholia, Schizophrenia, Paraphrenia and Paranoia, Mental Disorder due to Toxins, Mental Disorder due to Infections, Mental Disorder due to Syphilis of the Brain, Mental Disorder due to Head Injury, Mental Disorder Associated with Physical Disease, with Childbearing, Mental Decay, Mental Defect, and Moral Defect. The book concludes with chapters on Examination and Disposal of the Patient, Special Forms of Treatment, Legal Relationships, and Some Sociological Considerations. The recent developments in therapy through the use of reserpine and other drugs are of course not included. In short, while the book may be of some value to clinicians and medical students, it cannot be recommended as a sufficiently broad, biological approach to the subject.

PSYCHOMOTOR ASPECTS OF MENTAL DISEASE. *An Experimental Study.*

By H. E. King. Published for The Commonwealth Fund, Harvard University Press, Cambridge. $3.50. xiv + 185 pp.; ill. 1954.

H. E. King has done a fine job of collating and collecting the literature in a field that has been too little explored. The problems involved in making explicit the motor or non-verbal aspects of behavior are enormous, and King has taken a sound approach in setting up his tasks and orienting his evidence along the line of fine psychomotility, rather than gross. His review of the literature and his discussion bring out most of the work to date on the subject in good order.

There are, however, several criticisms which might be put forward. It is unfortunate that King did not stick with his title, descriptive of certain motor aspects of mental disease, instead of waxing philosophic, which was probably unwarranted from the data. It is unfortunate also that material illuminating certain aspects of non-verbal behavior, presenting methods for reduction of very complex action into a few simple tasks, would not stand on its own merits. One wonders at the necessity for postulating the centrality of motility as the unitary core from which other human experiential functions are derived or upon which they secondarily hang. Sperry seems to have taken a similarly one-sided view. It seems almost a scientific necessity nowadays to make the grand discovery; it is not satisfying enough to add to knowledge.

There is little basis, from the standpoint of philosophic necessity, for urging the primacy of any particular form of experience to which our attention is directed over others. Such a distortion is assuredly necessary in the process of fractionating material for examination, but can be of little assistance in reassembling the observed into its more ordinarily experienced whole. One is very much in the position of the seven wise men and the elephant. The point of view of an approach must be seen for what it is, partial and not total, nor can such a jump be made from the data presented.

Several minor criticisms are in order. Considering the variations in mean tapping, for example, arrived at by different investigators such as Shakow and Huston, King and Clausen, and King himself, one wonders at the use of a base-line technique that cites the normal and percentage of normal as the most reliable index of the meaningfulness of such variation in order to assess the findings.

The basis of comparison parallels so closely what one might expect, as the author says, from a "common sense point of view," when relating degree of apparent illness to reduction in performance, that such an ex-

planation seems most reasonable until better evidence than the present is brought forward. The conclusion that motivational factors play little role in task-oriented behavior is surprising to one who has worked with very sick patients. The further remark that learning is essentially the same in performance among very retarded schizophrenics and normals also makes one wonder. These people may be able to learn at the same rate as others, but experience demonstrates that they are usually too preoccupied to try, which casts some doubt on the use of a clinical classification in comparing performance among the more disturbed patients. The diagnostic category of pseudoneurotic schizophrenia also is still too ill-defined in the borderlands of schizophrenia to separate it either from the schizophrenics, on the one hand, or the neurotics, on the other, for purposes of scientific comparisons based upon it.

All in all, however, the book is a good piece of work and a good starting point for much-needed further work in its field.

JORDAN M. SCHER

THE CLINICAL INTERVIEW. *Volume One: Diagnosis. A Method of Teaching Associative Exploration.*

By Felix Deutsch and William F. Murphy. International Universities Press, New York. $10.00. 613 pp. 1955.

This is an important and valuable book representing a significant step in the rather painfully slow and confused development of the clinical interview. It is the first of a 2-volume series and deals with the diagnostic application of the sector method and associative anamnesis technique first introduced by Deutsch 15 years ago and later presented in a small handbook (*The Associative Anamnesis*).

The Clinical Interview is offered primarily as a textbook for teaching psychiatric residents and others "who are interested in improving their own unique approach to the problem of interviewing and psychotherapy." Both authors have had considerable experience in teaching their methods at the Boston and Cushing V.A. Hospitals.

Drs. Deutsch and Murphy criticize current methods of education, stress the need of adjusting treatment to "levels of patient operation," emphasize the role of ego function and its defenses and warn against preoccupation with genetic considerations. The most important goal in psychotherapy is the acquisition of insight and its communication to the patient. The objectives of goal-limited therapy include making repressed material conscious, relieving anxiety by abreaction, and the resynthesis of conscious and unconscious ego function.

Associative anamnesis "is an interviewing method based on the concept of free association as used in analysis," a method in which the patient's verbalization and thoughts are guided and maintained in emotionally significant sectors. The general plan of the book is similar to the authors' teaching method. First there is a condensed but fairly thorough presentation of the psychoanalytic dynamics operative in a particular syndrome. This is followed by a brief case report emphasizing the interpersonal relationships in and out of the family constellation. Then there is a preliminary discussion of the anticipated interview. Next a verbatim recording of the interview, with a running commentary on what "went on in the mind of the patient and interviewer." A final discussion, follow-up report, and an elaborate diagram complete each chapter. An excellent bibliography is appended.

In anticipating adverse criticism and answering previous objections leveled at their method, the authors suggest that a careful reading of their book will dispel the misconception that the associative anamnesis technique is "unsubtle and unfeeling" or that the therapist plays too passive a role by merely repeating the patient's words. One of the most serious defects of this book, as well as of Dr. Deutsch's previous manual (*Applied Psychoanalysis*), is the relatively cursory treatment of the technique itself. In a book of over 600 pages, the authors devote less than 10 pages to the systematic discussion of their technique. It is perhaps understandable that misconceptions have arisen and that many find themselves impressed but inadequately instructed.

Those who do not accept basic Freudian postulates and who feel that orthodox psychoanalysis involves unsubstantiated and "wild" interpretations may experience considerable difficulty in following the development of the recorded interviews and may find themselves in frequent disagreement with the interviewers' assumptions. Incidentally, since patients in this type of therapy or interview seldom become aware of or can utilize such basic insights, one wonders why interpretations (in the running commentaries) at the "deepest" level are so frequently made.

The above remarks are not made to decry the importance or value of this work. On the contrary, Drs. Deutsch and Murphy have so much to contribute to the theory and practice of psychotherapy that I for one regret the frustrations engendered by this book's shortcomings, and eagerly await the second volume on *The Clinical Interview*. Regardless of one's psychiatric or analytic orientation, a careful perusal of what Drs. Deutsch and Murphy have written can only prove to be of value to both neophyte and expert.

MEYER STEINBACH

PSYCHOANALYTIC PSYCHIATRY AND PSYCHOLOGY. *Clinical and Theoretical Papers. Austen Riggs Center, Volume 1.*

Edited by Robert P. Knight and Cyrus R. Friedman; papers by Aaron T. Beck, Margaret Brenman, Erik H.

Erikson, Merton M. Gill, Robert P. Knight, David Rapaport, Roy Schafer, and Allen B. Wheelis. International Universities Press, New York. $6.00. viii + 391 pp. 1954.

This is the first in a promised series of publications to collect the work of the staff members of the Austen Riggs Center in Stockbridge, Mass. This volume is divided into 3 major sections: theoretical, clinical, and clinical psychological. Robert Knight, who heads the group, makes the largest clinical contribution in a series of excellent papers on psychotherapy and the treatment of borderline psychotic states. David Rapaport and Roy Schafer are the psychologists who contribute several stimulating and thought-provoking treatments of clinical and theoretical problems in the field of psychoanalytic psychology.

While a collection of published papers does not make always for the best integrated of books, this one does illustrate brilliantly the high quality of thinking among those who have succeeded to the tradition of Austen Riggs. This generation of workers, together now for only 8 years, is having an effect on psychiatric thinking that is poles apart—although no less valuable for all its difference—from that exerted by Dr. Riggs.

JEROME HARTZ

A WAY TO THE SOUL OF THE MENTALLY ILL. *Monograph Series on Schizophrenia, No. 4.*

By Gertrud Schwing; authorized English edition by Rudolf Ekstein and Bernard H. Hall; foreword by Frieda Fromm-Reichmann. International Universities Press, New York. $3.00. 158 pp. 1954.

The original German text of this small book was published in 1940 in Zurich. Fourteen years later its translation into English seemed still worthwhile. It is not difficult to realize the value and the particular appeal of this monograph: the author's direct approach to the problem at hand, the relative absence of scientific aspirations, the personal warmth and intuitive understanding of much that went on in her schizophrenic patients, her grasp of therapeutic possibilities and the devotion to her chosen work. Moreover, this book has a certain two-fold historical importance. Gertrud Schwing was among the first few psychoanalysts who ventured to treat hospitalized schizophrenics; yet she was not even a physician but a nurse, though trained by Paul Federn and working together with him. Since then—she worked in the Psychiatric Clinic in Vienna from 1935–1938—intensive psychotherapy with hospitalized schizophrenics has become accepted at least in this country. Methods and theories, varying from author to author, have been modified and have become more articulate. Yet it seems doubtful whether the actual therapeutic success has kept pace with this development. This book deserves the attention of psychiatrists and psychologists. Quite likely, however the psychiatric nurse, instructor, or student, will benefit even more from it.

A Foreword by Frieda Fromm-Reichmann and a Postscript by Hans Christoffel give special explanations and support to this book. Of particular interest is an Introduction by the two translators, Rudolf Ekstein and Bernhard H. Hall (both of the Menninger Institute), for it contains an account of Gertrud Schwing's personal communications concerning her unusual career and the motivations for her work.

WALTER O. JAHRREISS

ON APHASIA. *A Critical Study.*

By Sigmund Freud; translated by E. Stengel. International Universities Press, New York. $3.00. xviii + 105 pp.; ill. 1953.

Sigmund Freud's studies on aphasia in all probability constitute the most important of his neurological publications. Nevertheless in world neurology he is most remembered and most quoted because of his massive and monumental work on the unilateral paralyses of children (*Klinische Studien über die halbseitige Cerebrallähmung der Kinder*) which appeared in 1891, the same year in which his studies on aphasia were published.

It is in these latter, very critical, studies that Freud constructively criticized the prevailing minute localizing theories, originally introduced by Broca and Wernicke, and proposed, on the basis of Hughlings Jackson's earlier formulations, a variation of the alternative functional theory which by now has become part and parcel of our current neurological thinking. It is in this book, incidentally, that he coined and defined the term "agnosia," which has since become an integral part of the vocabulary of neurological science. Although these studies are seldom mentioned in most of the standard English textbooks, Nielsen nevertheless implies in his recent publication on the subject (Nielsen, J. M., *Agnosia, Apraxia, Aphasia*, 1947) that it must be considered one of the milestones in neurological progress.

It is in these studies of his on aphasia that Freud also developed the concepts of psychophysical parallelism and of over-determinism, both of which later on became of such fundamental importance in his studies of the unconscious and in the development of modern psychoanalytical theory. It seems incredible, therefore, that, as Ernest Jones states in his *The Life and Work of Sigmund Freud*, only 257 copies of this work were sold during the 9-year period following its publication, and that Freud received only $62 in royalties for it. This work is recommended reading for all who are interested in psychiatry, neurology, or the history of medicine.

If Freud had never made any of the investigations which now constitute the cornerstone of psychoanalytic theory and practice, he would nevertheless, in all proba-

bility, be remembered in the history of medicine because of his work in both pharmacology and neurology. The publishers have therefore done a real service to American medicine by reissuing—and in English—these long-neglected and exceedingly significant studies of Freud on aphasia.

HAROLD ROSEN

PSYCHOLOGY AND ANIMAL BEHAVIOR

THE PRACTICE OF PSYCHOTHERAPY. *Essays on the Psychology of the Transference and Other Subjects. Bollingen Series, XX.*

By C. G. Jung; translated by R. F. C. Hull. Pantheon Books, New York. $4.50. xii + 378 pp. + 3 pl.; text ill. 1954.

The Practice of Psychotherapy is the third volume in the projected series of the collected works of C. G. Jung. It comprises all of Professor Jung's papers on the subject of psychotherapy which were between 1929 and 1951, and includes *The Psychology of the Transference*, which has been published as a separate volume in Switzerland (1946). The latter is a lengthy analysis of the 16th century alchemical opus, *Rosarium Philosophorum.*

Jung's essays cover a wide field, extend well beyond the ordinary framework of psychotherapy, and encompass a critical analysis of the "reductive" methods of Freud and Adler, and a presentation of his own philosophical and theological psychology with repeated reference to the "collective unconscious." The latter concept becomes increasingly the very cornerstone of the author's metapsychology. Other articles deal rather exhaustively with catharsis, transference and countertransference, dream analysis, and technique. Jung claims to have been the first to recommend prior analysis for the therapist, he emphasizes the significance of the manifest dream, and advocates flexibility in methodological approach.

For my part, I closed this compilation with mixed feelings. On the positive side, these papers are well-written, in the usual beautiful prose of the author. Jung's ideas are interesting and challenging, and his argumentation is often compelling. One can scarcely be unaffected by his pleas for flexibility and unfettered and unbiased thinking. Finally, I shall remain permanently grateful for being introduced to the *Rosarium Philosophorum*, not because I feel that we must go to the mystic meditations of medieval medics for our psychological principles, but rather because the work shows how full of insight, how intuitively wise was this philosophy of the Middle Ages, stripped of its magical ritual and obfuscating symbolism.

On the critical side, I have asked myself the question repeatedly: Why hasn't Jung attracted more followers, in this country at least? Why doesn't he have more influence in allied fields? He certainly deserves a wider audience, and yet few people have even read him. Can it be because of his somewhat fantastic theory of the "collective unconscious" with its "primordial images" and "archetypes"? Jung has apparently had repeated experiences which convince him of the validity of these phenomena, but hardly anyone else has reported them. Or is it because of his own skepticism and the vagueness of his basic principles? Can it be because of the admixture of philosophy, ethics, and religion? Is his analytic psychology consistent with modern scientific criteria and methodology? It is difficult to subscribe to many of Jung's criticisms of Freud or some of his own unique views, but one cannot, on the other hand, agree with Glover's devastating critique. Mullahy's analysis and Clara Thompson's commentaries are more generous to him, and posterity may well place its judgment somewhere between these views. Let the reader decide for himself, and if he cannot, let him at least enjoy an intellectual and emotionally stimulating treat.

MEYER STEINBACH

THE DEVELOPMENT OF PERSONALITY. *The Collected Works of C. G. Jung, Volume 17. Bollingen Series, XX.*

By C. G. Jung, translated by R. F. C. Hull. Pantheon Books, New York. $3.75. viii + 235 pp. 1954.

Jung's writings are being translated and reprinted in an 18-volume edition, of which this volume, Number 17, is the fourth to be published. The book contains two previously untranslated papers, but most of the remaining six have been retranslated or revised somewhat in preparation for this edition.

While this group of papers is valuable in giving some understanding of Jung's attitudes and ideas about personality development and the factors which either contribute to or stunt it, the reader will not be able to gather from this volume a full idea of Jung's conceptions. This is only natural, as the papers presented here largely represent lectures prepared for educators or other papers prepared to deal with specific topics. One gets, however, glimpses of Jung's opinions concerning the nature and interpretation of dreams, the nature of symptoms, the symptomatic character of the Oedipus Complex, and the major groups of psychic disturbances in children. The translation is easy and interesting to read, but especially in relation to points of major theoretical interest the words often seem to lose denotative significance.

CHARLES N. COFER

SCIENCE AND MAN'S BEHAVIOR. *The Contribution of Phylobiology. Including the complete text of: The Neurosis of Man.*

By Trigant Burrow; edited by William E. Galt. Philosophical Library, New York. $6.00. xii + 564 pp. + 6 pl.; text ill. 1953.

This one volume contains two works: *Science and Man's Behavior*, and *The Neurosis of Man*. The latter is a reprint of Trigant Burrow's last book, the other represents a unique commentary to it. While the printing of *The Neurosis of Man* was delayed in 1948, Burrow sent various chapters in advance with an accompanying letter to outstanding men in different fields of science. The answers and remarks of 29 of them were finally assembled and discussed under six topics. More urgent work and in the end his fatal disease (January, 1950) prevented the completion of this compilation by Burrow himself. William E. Galt, his close collaborator at the Lifwynn Foundation in Westport, Connecticut, finished the remaining chapters, "drawing material primarily from Dr. Burrow's letters to scientists and his unpublished writings." This completion was done with admirable skill; nowhere is there a suggestion that anyone else but Trigant Burrow wrote it word for word himself. The editor's advice is to read *The Neurosis of Man* first. Indeed, the collected correspondence complements the main work and may help to clarify some of its difficult points. It is not an easy task to read it, despite its apparently deliberate repetitiousness.

In *The Neurosis of Man*, Trigant Burrow deals first with Interrelational Man, and gives the "symptomatology of human behavior." This part is called Phyloanalysis, while the second part, a "phylosynthesis," bears the title Organismic Man or The Biology of Human Behavior. Early in his psychiatric career the author realized that the science of human behavior cannot be built on the study of the individual alone. Man is always in relation to others and to the world around him. The properties of group-functioning must be studied and man must be understood in an organismic frame of references in order to find the principles that underlie and regulate the behavior of man as a species, a race. Therefore, the term "phyloanalysis," which replaced the original one of "group-analysis." The author is quite explicit about the fact that his work has nothing to do with the more recently developed group therapy.

In the famous Lifwynn Foundation the continuous, relentless, and individually painful studies "of the group by the group" were carried out in the hope of finding the basic factors underlying man's conflict and disorder. The author and the members of this group came to realize that the typical, "normal" behavior of man is—without exception—neurotic. "Normality" is but the social reaction-average of an artificially conditioned species. It is not healthy behavior. It has been artificially deflected from what it primarily, biologically *is*. Man as a global community or race suffers from a "social neurosis." None of us realizes to what extent unconscious systems of prejudice and wishful thinking have become fashioned into a pictorial self that is biologically alien to the organism. Our behavior is governed by a pseudo-identity or "I"-Persona. Language and the false use of symbols have made it possible for man to believe as his fancy dictates, not as his senses ordain. But this device of man's symbolic ingenuity has recoiled upon man himself and henceforward he can only seek to explain with more symbols his own disordered state of mentation. This was man's fall, his original sin. The partitive, autopathic, affecto-symbolic mode of behavior over the primary motivation of the organism as a whole constitutes the physiological basis of both individual and social neurosis. Attention, our interest in objects and events, has become "ditention," a situational reaction in which ulterior advantage supersedes direct interest in an object or condition for itself. Ditention is invariably accompanied by an irrelevant, partitive interest—an interest that supplants and divides man's "cotentive" adaptation. Cotention, the native attention of the phylo-organism, is a form of homeostasis, that operates normally in all bodily activities. This ancient pattern of cotention is not beyond the reach of man; it is accessible to the organism's deeper levels of sensation and perception. Indeed, this pattern of wholeness is amenable to objective research, although it lies within one's organism. The author denies emphatically that to attain this pattern one has to adopt some Yogi practices; or that it has anything to do with a state of "Nirvana," or with mystic experiences. It is a "quite simple physiological appreciation of the function of one's own organism as a total entity."

I cannot myself follow Trigant Burrow's easy diving from the psychological field into the dark physiological waters. "Basically man's real conflict is phylophysiological," it is "ultimately traceable to a physiological conflict within the organism of man as a species." "The neural areas whose function controls the partitive or paratonic pattern of tension we may call parencephalon, while the functional areas of the cerebrum that regulate the organism's orthotonic pattern of tension as a whole we may call the orthencephalon. The area I demarcate functionally as the parencephalon corresponds in part at least to the area which the anatomists circumscribe—as the prefrontal zone." These and many similar statements are rather reminiscent of the attempt to localize brain functions even in accordance with the tenets of existential analysis.

This volume may well be considered a summing up of the author's findings, formulations, and theory as he expounded and developed them for about thirty years. Those who never heard of them will enjoy their originality, and no matter how far and how often the reader will disagree with the author's statements and conclusions, he will pay respect to Trigant Burrow's singular devotion to his task and to his unwavering search for the truth; to his deep concern about man and his fate; and to his burning desire to lead man back to the lost paradise of wholeness, oneness, unity.

Perhaps, too, the reader will remember some other books which deal with the "need of our time" to gain or regain unity, individually and among groups and nations: as, for instance, L. L. White's concept of the unitary man in *The Next Development in Man*, or Pitirim A. Sorokin's *The Reconstruction of Humanity*.

WALTER O. JAHRREISS

MAN AND HIS MOTIVES. *An Approach to Adjustment and Remotivation.*

By Ernest Windle and James W. Marsh. Exposition Press, New York. $3.00. 197 pp. 1954.

This book was written by two former newspapermen, one now a municipal court judge and the other at one time an engineer. The fundamental conception seems to be that ideals are motives and that behavior patterns may be corrected by changes in ideals. But this argument is not developed or supported by evidence of any sort. Rather the book is a hodge-podge of misinformation (such as that the cerebellum is the seat of sensory centers), religion, and mysticism. Despite the authors' good intentions, their product cannot be recommended to anyone.

CHARLES N. COFER

MOTIVATION AND PERSONALITY.

By A. H. Maslow. Harper & Brothers, New York. $4.50. xvi + 411 pp. 1954.

In this volume A. H. Maslow has collected a number of papers which were first published in journals. Together with new material, they constitute both a vehement attack on certain widely accepted doctrines concerning motivation and suggestions as to the directions motivational theory should take. While I cannot recommend it as a textbook, because of its rather difficult style and because it is essentially a polemic, it is nevertheless a book which every student of motivation must take very seriously.

Many of the major arguments against both traditional instinct theory and theories which stress the acquisition of motives through processes of associative learning are well taken and point up serious present deficiencies in such conceptualizations. Likewise, the rejection of tension reduction and the rejection of the exclusive use of the animal (rat) model and of the abnormal (neurotic) model as the basis for a general theory of human motivation would seem to offer the prospect for a fresh look at motivational phenomena in the human. But Maslow's solution is essentially a non-motivational one. That is, he sees the goal of human development in the concept of self-actualization, a notion very similar to those expressed by such writers as Kurt Goldstein, Erich Fromm, Rollo May, and Carl Rogers, and which seems to mean that a man must do "what he is fitted for," that "what a man *can* be, he *must* be" (p. 91), or that one should "become everything that one is capable of becoming" (p. 92).

To achieve the conditions for self-actualization the other needs, like those for food, water, safety, love, esteem, etc., must be thoroughly satisfied, so that none will dominate behavior and so that their frustration may be tolerated. These needs have an instinct-like status, and the thesis here seems to be that satiation can relieve behavior of their dominance. So the self-actualized man is free of pressure from the ordinary motives or needs and is concerned only to realize his potentialities. Each such man is probably unique; certainly he would tend to non-conformity and be unpredictable from a conventional motivational point of view. Does not this mean that Maslow makes motivation something it is desirable to overcome, to be free of? If so, the motivation construct assumes a negative valence in this system as compared to its overriding positive evaluation in other theories. This may not be undesirable, but I think the implication needs raising. Further, is a science of self-actualized man possible? If so, what kind of science?

There are many interesting and valuable features of this book, such as the study of self-actualized people, but the theoretical points summarized above seem to offer the greatest stimulus to further inquiry concerning the problem of motivation.

CHARLES N. COFER

HUMAN BIOLOGY

ANTHROPOLOGICA. *Actes du Congrès International des Sciences Anthropologiques et Ethnologiques, Vienna, September 1–8, 1952. Vol. 1.*

Edited by R. Heine-Geldern, W. Koppers, and J. and M. Weninger. Adolf Holzhausens Nachfolger, Wien. $6.00. 326 pp.; ill. 1954.

Reviewing this volume is like sitting down to a 30-course Mandarin dinner and then trying to remember which course was the most palatable—the appetite is jaded too soon! There are 68 separate titles in the report: 34 articles on general anthropology, 18 articles on regional anthropology, and 16 abstracts.

The section on General Anthropology includes 11 articles on human heredity and ecology, 8 articles on anthropometry and morphology, 5 on human evolution and paleoanthropology, 4 on "applied" genetics, with special reference to paternity cases, and 3 each on the iris, and on skin and hair. Busanni-Caspari, in Anthropologische Untersuchungen an der Schädelbasis des Erwachsenen, concludes that prognathism is related to a short cranial base ($r = +0.41$). Korn, in Beiträge zur Morphologie des menschlichen Beckens, presents data on the pelvic inlet index of male and female Mon-

golids, Europids, Indianids, Negritos, Filipinos, and Melanesianids. Schmitz (Körperbau und Gesundheitsforschung) offers a suggestive analytic approach to the study of body build, by employing a blend of somatometry and embryology. In the erect position the anterior half of the body is dynamic (sense organs, and genitalia), the posterior half is static (bony systems for posture, occiput, scapulae, sacrum); the cephalic end is ectodermal in origin, the anterior (lower) trunk endoderm, the posterior trunk mesoderm, the limbs "parietal." The author believes that the establishment of "norm" types will be clinically (preventively?) useful. Ziegelmayer (Über die Beziehung des Irisbildes zur Gesamtkonstitution) concludes that the iris, in color and in structure, is related in part to individual constitution in terms of age, sex, habitus, endocrine balance, and social milieu. Torgersen (Genetic Dynamics of Human Evolution) uses the metopic and transverse occipital sutures to "justify the supposition that the mutations involved in these sutures are responsible for the divergence of the hominids from the ancestral stock." Routil (Erbbiometrische Studien an Papua und Melanesiern) recommends and demonstrates the use of family-line studies (stature, head L, head B) in race-type definition.

The part on Regional Anthropology includes 6 articles on Europe, 5 on Africa, 4 on Asia, and 3 on the Americas, most of which are craniological studies. Lisowski (A Report on the Skulls from Excavations at Sesebi, Anglo-Egyptian Sudan) reports on a study using the coefficient of racial likeness. The S. series is close to Kerma, Nubian D, and Naqada A and Q; some relation to modern Abyssinian-Tigré populations; very different from predynastic Badarian, El-Amrah and Hou groups of Upper Egypt, and 26–30 Dynasty Egyptian "E" of Gizeh in Middle Egypt. Imamura (Die Kopflänge, die Kopfbreite, und der Längen-Breiten Index der Völker in China, in der Mongolei, Mandschurei, und in Korea) presents a very useful distribution map.

The Abstracts include 5 articles on race (4 on Africa, 1 on Mongoloids), 4 on teeth and bone, 3 on skin, 2 on human evolution, 1 on hair, and 1 on blood groups. Bergman (The Fluorine Content of Pithecanthropus and of some Pilot Fossil Bones) shows that the *P. erectus* skull cap and femur are contemporary with the pilot bones, i.e., Middle Pleistocene.

This volume has only been sampled in this review, but I hope that the reader's appetite is whetted—there's a lot to feast upon!

W. M. KROGMAN

HOMO. *Internationale Zeitschrift für die vergleichende Biologie der Menschen. Organ der Deutschen Gesellschaft für Anthropologie. Band 2; Band 3.*

Edited by Egon Freiherr von Eickstedt. "Musterschmidt," Wissenschaftlicher Verlag, Göttingen. DM. 28.— per vol. (2) 192 pp.; ill. (3) 192 pp. + 1 pl.; text ill. 1951; 1952.

Rather than being a typical periodical publication, each of these volumes represents what might better be called a "Yearbook," appearing as a single annual number and in bound form. The contents run to 33–36 original research papers by German anthropologists, anatomists, and students of human genetics, together with reviews of anthropological publications elsewhere and news from workers in other parts of the world. This is a publication that without question will, from the beginning, be indispensable to all workers in the fields aforementioned.

THE FIRST AUSTRALIANS.

By Ronald M. Berndt and Catherine H. Berndt. Philosophical Library, New York. $4.75. 144 pp. + 16 pl.; text ill. 1954.

This pleasantly written and well-illustrated little book is oriented toward the lay public and is designed to convey to that group some appreciation of an aboriginal way of life that has all but disappeared. The authors have set out to show something of the way in which the native Australians lived, and what values it was that gave their lives meaning and color. Despite the limitations of a synoptic approach, this is no over-abstracted culture summary; and the reader is left with a sense of individuality among these highly adapted but simple folk that is frequently absent in writings for a professional audience. For biologists there are no new insights, and ecological materials are summarily presented in 6 pages. Nonetheless, this book has real merit for the reader seeking a sympathetic introduction to the aborigines of the world's driest continent.

JOSEPH B. BIRDSELL

TLATILCO AND THE PRE-CLASSIC CULTURES OF THE NEW WORLD. *Viking Fd. Publ. Anthrop., No. 19.*

By Muriel Noé Porter. Wenner-Gren Foundation for Anthropological Research, New York. $2.50 (paper). 104 pp. + 14 pl.; text ill. 1953.

The principal object of this study is "to analyze the newly discovered Pre-Classic or Formative Tlatilco culture of Central Mexico and to attempt to trace its relationships with other widespread areas of the New World." The author has become convinced in the course of her study that the relationships with Meso-America (Yucatan, Guatemala, etc.) and with Peru are so striking that there must have been some historical connection between them.

The Tlatilco site was a burial ground of a people who cultivated maize and ground it on metates, who produced a great variety of fine pottery, and who used simple tools such as stone axes, obsidian knives, and bone and antler implements. They practiced fronto-

occipital head deformation. Their clay effigies of birds and animals are realistic and those of the people themselves reveal much of their clothing and customs. The Tlatilco culture is placed in time as contemporaneous with the Middle Zacatenco Period (B.C. 200–A.D. 300) or somewhat earlier. Relations are also predicated with three cultures of the southeastern United States: Marksville of Louisiana; Santa Rosa-Swift Creek and Weeden Island of the Florida Gulf Coast; and the Hopewell culture, representing the peak of the Burial Mound period.

RACE MIXTURE.

By Harry L. Shapiro. UNESCO, Paris; [Columbia University Press, New York]. 25 cents (paper). 56 pp. 1953.

In this short account, the well-known Chairman of the Department of Anthropology at the American Museum of Natural History discusses in non-technical style the biological and social factors that interact in human race mixture. Estimates indicate that about one-sixth of the total population of the New World consists of people of mixed racial heritage. The total in the rest of the world, probably less than 6 million, is far less, yet by no means inconsiderable. The resulting race problem is considered from the standpoints of race consciousness, numbers, competition, culture, and the historical background of imperialism. A brief section on Biological Considerations is in general agreement with the views of the great majority of geneticists and anthropologists today. Though racial distinctions of a biological nature are undeniable, there is no sufficient ground for attributing innate superiority or inferiority to any particular race, either in physical traits or in respect to intelligence, with the possible exception of a few special characteristics, such as musical ability—and even here the evidence is slender. A section entitled Down to Cases is particularly interesting. Here Harry Shapiro discusses the Pitcairn Polynesian-English hybrids and points to the definite evidence of their hybrid vigor, manifested in both stature and fertility. The remarkable way in which the Pitcairn Islanders' development of their own unique culture embodied both Polynesian features transmitted through the women and English features transmitted through the men, together with a not inconsiderable amount of original ingenuity, is most fascinating. The study of Race Crossing in Jamaica by Davenport and Steggerda is also summarized briefly and their conclusions that the Browns were physically and mentally inferior to either the Negroes or the Whites are justly discounted on the ground of unrepresentative and inadequate sampling and a primitive conception of the general validity of psychological tests standardized for persons of a particular cultural background. Finally, the interesting Hawaiian melting-pot is examined.

Shapiro's general conclusions can hardly fail to meet the approval of scientists who have studied the facts, however hard it may be for some groups both in the United States and abroad to accept them. It is indeed worth emphasizing that "the economic and social inferiority of the parental groups can and often do place an especially heavy burden on their mixed progeny. . . . The great injustice, after all, that has been placed on the mixed-blood is that he is judged, not as an individual, an elementary right to which he is entitled, but as a member of a group about which there is much prejudice and little understanding."

BENTLEY GLASS

DE OMNIBUS REBUS ET QUIBUSDAM ALIIS

SCIENTIFIC WRITING.

By Meta Riley Emberger and Marian Ross Hall; general editor, W. Earl Britton. Harcourt, Brace & Company, New York. $4.50. xii + 468 pp.; ill. 1955.

This book is far more than just a manual devoted to scientific writing. It is a literary gem that will delight both the neophyte and the seasoned writer who seeks a text and reference book suitable to all phases of modern scientific writing. There is nothing pedantic about it. The reader at once notices the freshness and charming vigor with which the authors logically present material interspersed with examples and quotations from the world's great scientific literature, the new and old examples illustrating principles and practices within their respective fields. The authors, both of whom are well acquainted with the field of science, are members of the English Department of the University of Louisville.

The material presented is arranged in a very serviceable chapter sequence. Fundamental concepts that are so necessary for scientific methods and research are elaborated in Chapters I and II. The quotation, "The unity of all science consists alone in its method, not in its material," taken from *The Grammar of Science* by Karl Pearson, heads Chapter I.

Each chapter throughout the book carries even more appropriate quotations. The Problem Concept (Chapter II) is probably the most valuable to the beginner of scientific writing, but it will also give new insight to a veteran. The next four chapters outline the investigative project in the following order: definition and terminology; collecting data; analysis: methods and applications; interpretation: applying the principles of logic. Problems of composition fill the next three chapters. The various types of papers are discussed in chapters X to XIII, inclusive. Naturally, the last two chapters of the book consider the formal methods of graphic and pictorial illustration. To my knowledge, there exists no book which is as complete in necessary detail, so full of

good advice, and packed with such sound wisdom as this book. All is said without being schoolmarmish. In fact, a great deal of wit and humor enliven the book.

Appendix A (Readings and Word Lists) is an elaboration of each chapter through selected readings of notable writings to illustrate most effectively the subject under discussion. For example: The Problem Concept is illustrated by three classical writings, respectively from Claude Bernard, Abraham Flexner, and Santiago Ramon y Cajal. The word lists are helpful as guides to use and spelling. In Appendix B one finds types of business letters for various purposes such as applications, inquiries and replies, and letters designed to further good public relations.

This book will have a wide audience. All science writers, regardless of their years of duty or types of work, will find it profitable. Modern communication through the scientific paper or report must still conform to the basic concepts of scientific writing. From earliest times to the present scientists have discovered and found these concepts not only useful but advantageous. *Scientific Writing* traces this history through examples. The book appraises the modern scene and admirably presents the problems of writing facing the present-day investigator. Along with these presentations useful solutions are clearly offered. The style of the book is of such a nature that it will be an excellent text in any course designed for scientific writing. It is also for those who cannot take advantage of formal course work.

Each age or era adjusts its language and style to the customs of the period. *Scientific Writing* takes cognizance of most of the intricate, subtle, and shifting shades of meanings of the words, phrases, and expressions of our time. The over-all picture of our language, as it is applied to meaningful use in writing a scientific article, is viewed in an historical perspective. This and many other features make the reading of this book a fascinating experience. It is a book directed to a specific purpose, yet has a broad and useful base. If Raymond Pearl were living, it is my hunch that he would have included it in his great little book *To Begin With.*

PAUL G. ROOFE

THE ITINERANT IVORY TOWER. *Scientific and Literary Essays.*

By G. E. Hutchinson. Yale University Press, New Haven; Geoffrey Cumberlege, Oxford University Press, London. $4.00. xii + 262 pp. + 1 pl.; text ill. 1953.

For nearly ten years every American member of the Society of Sigma Xi turned eagerly, upon receiving a fresh copy of *The American Scientist*, to a section of the magazine called Marginalia. Here he could always expect to find an essay evincing brilliant exposition, fine literary style, and an astonishingly broad and deep knowledge of modern science, especially its biological aspects. These Marginalia are now no more, for the author of them, feeling the pressure of other work, has resigned his post as a Contributing Editor. The scientific public is much the poorer for this decision by G. Evelyn Hutchinson, Professor of Biology at Yale University, for there are indeed very few who would dare to try to succeed him in the task of interpreting science to scientists in fields other than their own. Yet surely never has the need for this been greater. It is accordingly with great joy that scientists will welcome this collection in book form of 23 of the outstanding essays by Hutchinson, all but 5 of which represent the Marginalia. One of the remaining five, the concluding essay in the book, has never been previously published.

The titles of the essays are sufficient to display the classical erudition with which Evelyn Hutchinson approaches his scientific writing: For Now the Morning Draweth Neare; The Gothic Attitude to Natural History; Time, Temperature, and the Birth of Aphrodite; Barbara sirenum melos dulcedine vinco; The Chrysanthemum and the Sword; Tuba mirum spargens sonum; etc. The subjects are as varied as their titles, ranging from the borderlands of science in the form of rhabdomancy and precognition, to fundamental ecology (The History of a Lake; On Living in the Biosphere), zoology (The Importance of Ornithology), and anthropology (Toward a Translation from the Feminine; Kroeber on Culture and Huntington on Heredity and Environment). Most stimulating of all are those essays that undertake to relate the concepts of seemingly distantly related themes, as in the essay on time, temperature, and Aphrodite, in which Hutchinson considers the light shed on the origin of life by means of physical and chemical methods, such as radiocarbon dating, the measurements of temperature in ancient seas by means of oxygen isotopic studies, and estimates of the age and origin of the oceans from amounts of argon-40. The essay Why is the Atom So Small? is particularly stimulating.

Some of Professor Hutchinson's positions on controversial subjects, such as the scientific validity of extra-sensory perception, will appear dubious to many scientific readers. Even in these instances, however, his well-considered point of view is suggestive and never to be discarded lightly. When, on the other hand, he writes of The Function of a University, or on Methodology and Value in the Natural Sciences in Relation to Certain Religious Concepts, or when he pays tribute to such figures as Sir Thomas Browne (Tuba mirum. . .), Rebecca West (The Dome), or to one so singularly shaped in his own mold, D'Arcy Wentworth Thompson, then indeed Evelyn Hutchinson is unsurpassable.

BENTLEY GLASS

THE CHALLENGE OF OUR TIMES. *Contemporary Trends In Science and Human Affairs as Seen by Twenty Professors at the University of Wisconsin.*

Edited by Farrington Daniels and Thomas M. Smith.

Burgess Publishing Company, Minneapolis. $3.50. x + 364 pp.; ill. 1953.

This is an enlightened and serious group of comments on the problems of our times, written for concerned citizens. It should be of interest to civic leaders, editorial writers, religious groups, and the like. It is based on a very successful course, "Contemporary Trends in Modern Civilization," given at the University of Wisconsin by a varied group including natural and social scientists, historians, and philosophers. It discusses, simply and rather briefly, basic aspects of modern physical science, with emphasis on its social and political impact; world economic problems and pressures; the social uses of intellectual freedom; and the approach to world government. It can be highly recommended as food for the thoughtful, with the qualification that, rather more than one feels in this book, our times are a challenge to our hearts, as well as to our heads. But such considerations as are presented here are the soil from which must grow the strength to, in Quaker terms, "Speak Truth to Power."

EVELYN HOWARD

SCIENCE IN PROGRESS. *Eighth Series.*

By George Gamow, Walter Orr Roberts, Joseph Kaplan, F. M. Carpenter, D. M. S. Watson, Donald R. Griffin, Paul R. Burkholder, E. Newton Harvey, Charles H. Townes, and George Scatchard. Edited by George A. Baitsell. Yale University Press, New Haven; Geoffrey Cumberlege, Oxford University Press, London. $6.00. xvi + 285 pp.; ill. 1953.

With the appearance of its eighth series of *Science in Progress* the Society of the Sigma Xi continues its high standard of presentation of reports describing current scientific research. As in previous series, the latest volume is based principally on material presented in the National Lectureships sponsored by the Society. In each case the subject is presented by an eminent authority in the field. This volume contains the following articles: The Origin and Evolution of the Universe, by G. Gamow; Unsolved Problems of the Sun's Atmosphere, by W. O. Roberts; The Earth's Atmosphere, by J. Kaplan; The Geological History and Evolution of Insects, by F. M. Carpenter; Africa and the Origin of Man, by D. M. S. Watson; Sensory Physiology and the Orientation of Animals, by D. R. Griffin; Cooperation and Conflict among Primitive Organisms, by P. R. Burkholder; Luminescent Organisms, by E. N. Harvey; Microwave Spectroscopy, by C. H. Townes; and Molecular Interactions in Protein Solutions, by G. Scatchard.

Those who have not had the good fortune to become familiar with previous volumes are urged to introduce themselves to the series by perusing Series VIII in the assurance that it continues the tradition of authoritative reports of interest to the specialist and layman alike.

V. G. DETHIER

SCIENCE AWAKENING.

By B. L. van der Waerden; English translation by Arnold Dresden, with additions of the author. P. Noordhoff, Groningen, Holland. $5.00. ii + 306 pp. + 28 pl.; text ill. 1954.

The Professor of Mathematics of the University of Amsterdam has written for the educated layman of Holland an early history of mathematics, which has here been translated by Professor Arnold Dresden of Swarthmore College. It covers the development of mathematics from the dawn of history to the beginning of the Middle Ages, with special emphasis on the contributions of Babylonian empiricism to Greek rationalization. The title is misleading; there were scientific pursuits other than astronomy, geometry, algebra, etc., which were awakening in this period. In short, there is not even a nod in the direction of biology. The book is beautifully printed and illustrated, and charmingly written, enough to hold even a biologist fascinated.

E. L. WHITE

DETERIORATION OF MATERIALS. *Causes and Preventive Techniques. A Collaboration under the Joint Auspices of the Services Technical Committee of the Department of Defense and the Prevention of Deterioration Center, Division of Chemistry and Chemical Technology, National Academy of Sciences, National Research Council.*

Edited by Glenn A. Greathouse and Carl J. Wessel. Reinhold Publishing Corporation, New York. $12.00. xviii + 835 pp. + 1 pl.; text ill. 1954.

The economic significance of deterioration in materials is amply illustrated by some of the quoted estimates: American railroads replace ties annually to the value of $160 million; termite damage costs this country about $40 million annually; the damage to textiles by moths costs us over $100 million each year; and the total annual cost to the United States may reach $12 billion. The present volume comprises 15 chapters by various authors, well edited and unified by the Director and Associate Director of the Prevention of Deterioration Center, National Research Council. It presents in clear and fairly simple language the present status of knowledge and practice in this important field, without going into detail about specific causes, mechanisms, or preventive procedures. "Intended as a reference work and source book on the techniques of deterioration prevention, it attempts to extract the rather limited number of general principles from the mass and to present them as an introduction to the various aspects of deterioration problems." The first 3 chapters describe the factors producing deterioration, the next 7 discuss the types of destruction occurring in various materials, 2 more deal with degradation in assembled units, and the last 3 review certain special aspects such as dehumidification, packaging, and the toxicity of preservatives. Extensive bibliographies appear at the ends of the chapters.

Heat, sunlight, moisture, wind, and dust are held to be the prime factors of deterioration, while biological agents are considered to play only a secondary role. Nevertheless, these biological agents present a formidable array, and obviously contribute very largely to the total loss. Fungi, bacteria, actinomycetes, algae, wood-destroying insects, other damaging insects, marine organisms, and rodents are described in sufficient detail for appreciation by the non-biological technologist; but the biologist will learn little from these accounts that he did not already know. He may, however, be surprised by the variety of materials attacked by the various living agents, and the extent of their depredations. He should also be much in sympathy with the authors' plea for more systematic and detailed research, if only to solve such important questions as the exact mode of action of destructive enzymes, the precise operation of anti-biological agents, or the fundamental nature of repellancy. He will undoubtedly find the extensive references most useful in pursuing current knowledge on detailed aspects of biological operation.

DOUGLAS H. K. LEE

APPLIED ELECTRON MICROSCOPY.

By Robert B. Fischer. Indiana University Press, Bloomington. $4.85. xiv + 232 + ii pp.; ill. 1953.

The author has undertaken the arduous, often thankless, but nonetheless necessary task of explaining a basic research tool in terms of its principles, construction, limitations, and operation. All too frequently it is forgotten that the scientist interested in fundamental problems can progress only so far as his techniques and equipment permit, and a solid grasp of the workings of his tools is necessary if he is to extract as much from them as is humanly possible. This is particularly true for the electron microscope, now barely in its teens, yet opening up new horizons of morphology with bewildering speed. Those who make use of the instrument, or the information gained from it, would do well to peruse what R. B. Fischer has to say. It is a modest, yet informative and pertinent book.

SCIENTIFIC, MEDICAL, AND TECHNICAL BOOKS *Published in The United States of America. A Selected List of Titles in Print with Annotations. Second Supplement: Books Published 1949–1952.*

Edited by R. R. Hawkins. Prepared under the direction of The National Research Council's Committee on Bibliography of American Scientific and Technical Books, Washington. $10.00. xii + 580 pp. 1953.

The comments made at the time of the original appearance of this bibliographical work (*Q. R. B.*, 22: 103. 1947) still apply to the successive supplements, of which this is the second. Monumental in size and compiled with great care, so as to be virtually free of errors, it gives an excellent idea of the variety of scientific and technical books published in the United States within the 4-year period it covers. Included are 17 publications in paleontology, 70 in biology, 74 in botany, 91 in zoology, 20 under the heading "Man," 29 under human anatomy, 57 under physiology, 35 under biochemistry, and 20 under bacteriology. During the same 4 years the *Quarterly Review of Biology*, with a broader topical and an international coverage, reviewed approximately 2000 items, or about 5 times as many. Of these, more than half were published in the United States. Consequently it can be seen that the mammoth volume under discussion is scarcely a complete listing of all publications that fall within its scope. Neither, for that matter, is the book review section of the *Quarterly Review of Biology*. If used with a knowledge of its limitations, *Scientific, Medical, and Technical Books* is nevertheless of very great value, and every good biological library should have one for reference.

In addition to the usual bibliographic information, the contents of each listed book are given, and further brief notes on the nature of the work are made. The comments are intended to be informative rather than critical.

THE QUARTERLY REVIEW OF BIOLOGY publishes critical reviews of recent researches in all of the special fields of biological science. The contribution should present a synthesis or digest of the researches and a critical evaluation of them. A mere synopsis of the literature without evaluation or synthesis is not desirable.

Theoretical papers are published occasionally, especially when such papers (1) include a critical synthesis of the literature bearing on the theory and (2) are likely to promote further research in a given field.

The article should be written in concise language, yet in sufficiently non-technical form as to be intelligible not only to specialists in other fields but to the general biologist as well. To this end the article should have a general introduction and a summary which enumerates one by one all of the principal facts and conclusions given in the paper. Interpretative diagrams and schemes are very desirable.

Material ordinarily taking the form of footnotes is set in small print and placed in the text and consequently should be written in a style so as to fit readily into the text. Acknowledgments are printed in the text in small type at the end of the article just preceding the List of Literature. Recent issues of the Quarterly should be examined for style as regards (1) section or subsection headings in the text, (2) literature citations in the text, and (3) List of Literature.

The subjects and authors of articles are selected by the Editors and members of the Advisory Board. Unsolicited articles which conform with the objectives of the Quarterly will be considered for publication.

A feature of the REVIEW is the section dealing with *New Biological Books*. In this department the book literature of different countries in the field of Biology is given prompt notice.

The QUARTERLY REVIEW OF BIOLOGY is issued in March, June, September and December.

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Books for Review may be sent to Dr. H. B. Glass, Department of Biology, The Johns Hopkins University, Baltimore 18, Maryland.

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